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# STAVE PIPE—ITS ECONOMIC DESIGN AND USE.

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This subject, in one or more of its aspects, has been briefly dwelt upon at various times by engineers when describing the construction of hydraulic works involving the use of pressure pipe of this type, but a full discussion of the various practical and economic problems involved in stave pipe design, and the determination of its real place among standard types of pressure pipes, have yet to appear.

The great dissimilarity in practice indicates either a very general unfamiliarity with the principles involved, or much difference of opinion regarding their practical application. That there is need for a better understanding of these principles, and of the correct limitations of the pipe's successful and economic usefulness, is apparent from the not infrequent partial disasters that have attended its attempted construction. That it has today a place among standard types of construction is apparent from the remarkable degree of favor accorded it by every one who has used it intelligently. The author firmly believes that the use of this pipe, now chiefly confined to the West, is destined to receive greatly extended recognition among engineers everywhere.

These considerations seem sufficient to warrant this presentation, which it is hoped may serve as a starting point for the evolution of clearer and more generally accepted ideas relative, not alone to the details of stave pipe design, but to the broader question of the com-

48-28. Pipe Line—San Gabriel Power Co.

parative economies of different classes of pressure pipes—a question which recent important experiments and accumulating experiences have done much to reopen to argument.

In treating the subject, the author proposes to discuss the essential considerations in stave pipe design, and some of the practical and theoretical limitations imposed. Supplemental thereto a study will be made of several existing pipe lines, with reference to the details and factors used and the attendant results; and, finally, having outlined a simple and rational method for making a safe and economic design, a comparison will be made between the leading types of large pressure pipes, with reference to their relative first cost, durability, carrying capacity, and minor considerations, from which the author will seek to determine the rightful place of stave pipe in economic construction.

## GENERAL TYPE CONSIDERED.

At first stave pipe was principally used for pen stocks in the development of water power, and was built in tapered sections which were put together after the manner of stove pipe. Apparently the first instance of its use as a continuous tube was the 6-foot penstock constructed at Manchester, N. H., in 1874, by J. T. Fanning, M. Am. Soc. C. E., and which is still doing service. Bands of round section were suggested by certain letters patent as early as 1880, and were first put into extensive use at Denver, Colo., in 1883. The particular type referred to in this paper is that which has been thus evolved, i. e., a pipe which is built continuously in the trench of staves of variable length, having radial edges and concentric faces, and which are held together by metal bands usually circular in section and spaced in accordance with the demands of the strains imposed.

In the design of a wood-stave pipe, the following essential points require consideration: The staves must be thin enough to secure complete saturation and to deflect readily to the degree of curvature employed, and they must be thick enough to prevent undesirable percolations through them. The bands must be of such size that, when spaced to secure the desired factor of safety against rupture, there will at the same time be no sensible flexure in the staves and no destructive crushing of the fiber beneath the bands. While fulfilling these conditions, the proportion between the thickness of the

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staves and the strength and spacing of the bands must be such that the swelling of the wood will not produce injurious strains upon what might otherwise be a properly proportioned band.

These are the primary considerations, generally stated, which should govern all design, and the author believes it will be profitable to consider them in detail, to point out some of the limitations of each, the effect of certain practical considerations, and to reduce the whole to a form easy of application. To do this intelligently a clear conception of the nature and source of the probable strains set up in the construction and operation of the pipe should first be secured.

## SOURCES OF STRAIN.

The tensile strains resisted by the bands are from three sources:

(1) The initial strain, caused by cinching during construction.

(2) The pressure of the water within the pipe.

(3) The swelling of the staves.

The strains resisted by the staves are from the following sources:

(1) The compressive strain of the bands.

(2) The compressive strain upon the edges of adjoining staves.

(3) The pressure of the water producing flexure of the staves between adjacent bands.

The fact that most of these strains, in their amount and importance, are more or less inter-dependent makes any separate determination of the values of each impossible without coincidently determining the nature of their mutual relation under some variety of conditions.

## CINCHING STRAIN.

It is evident that to secure a pipe that shall be tight, or practically so, when first filled, the initial cinching strain must be sufficient in extent to produce:

(1) A degree of compression per square inch between the staves in excess of the water pressure.

(2) A uniform contact between the band and all the staves; and, if the band be of a curved section, a sufficient indentation of the wood to afford the band a bearing contact sufficient in area to resist, without further immediate indentation, the water pressure incident to the filling of the pipe.

If these conditions are not complied with, it is evident that leakage must ensue until the necessary compression between the

staves, and the requisite area of contact between the bands and the staves are supplied by the swelling of staves. Whether this will be accomplished or not will depend chiefly upon the degree of seasoning of the staves. That the question of seasoning, in securing tight pipe, so long as the staves are uniform, is relatively unimportant, with proper cinching, seems to follow logically, though the practical difficulties incident to the handling and shipping of the heavier green timber, and the prevention of unequal shrinkage before getting the staves into the pipe, usually make the at least partially seasoned timber the cheaper. It is apparent that back-cinching, to a degree productive of greater compressive strain than is essential to the foregoing requirements, is to that extent a needless addition to the cost of erection and to the band strain.

Owing to the friction between the band and the staves, and the compressive resistance of the wood, it is not found possible in practice to secure the necessary area of contact, under a band of curved section, by screwing up the nut at the end of the band, without inducing an objectionably high strain. To accomplish the result in a better way, the band is usually pounded vigorously at all points, simultaneously with the use of the wrench. Such a practice is highly commendable, and is, indeed, usually essential, as it tends to secure the proper degree of indentation with the least residual tensile strain in the band consistent with securing requisite compression between the staves.

Just what this cinching strain usually amounts to in practice depends upon the character of and the manner of doing the work, and is probably as variable as individual judgment. So far as it influences the success of the work, it is believed that the foregoing sufficiently elucidates the principles involved. In its effect upon the final working strain in the band, it will be shown later that a considerable variation in practice within reasonable limits will not seriously affect the final stresses, though, doubtless, much affecting the temporary strains resulting on first filling.

### WATER PRESSURE STRAINS.

The strains induced in the bands by the pressure of the water within the pipe are susceptible of positive determination, and the methods of their solution are too well known to require any explanation herein.

STRAINS FROM SWELLING STAVES.

The additional strain caused by the swelling of the staves is less easily determined, and exists only within certain limitations of the first afore-mentioned source of strain.

With swelling timber, as with a steel spring, it may be assumed that its expanding power at a given stage of compression well within what may be called its elastic limit, is measured by the load necessary to produce that compression under like conditions. Hence its ultimate swelling power, at a given degree of compression, is the measure of its ultimate resisting power. It is also influenced by the hardness, direction of grain and such other conditions as affect the compressive strength of timber within its elastic limit when resisting forces applied across the grain.

If, then, the staves in a pipe be compressed laterally by the bands beyond the elastic limit of the saturated wood, there can be no swelling of the staves, and consequently no increased strain in the bands from this source. On the contrary, a farther compression of the fiber will result until an equilibrium is established between the compressive strain and the sustaining power of the wood; and if the sustaining power is below that requisite to resist the pressure of the water, leakage will of course result. If, on the other hand, the compression is less than the corresponding swelling power of the wood at the degree of seasoning and compression used, the timber will, by swelling when wet, develop an expanding power in some degree commensurate with the ratio of the volume of the uncompressed saturated stave to the same when compressed to the degree used, which expansion, of course, induces a correspondingly increased strain in the bands.

Thus there results the rather remarkable condition that if the bands, in resisting the water pressure, tax the staves beyond the limit of their permanent compressive strength, they, by yielding, release the excess of pressure, and leakage results; and if less is required of them than the most they are capable of giving, they force the band to take all the additional strain they are capable of exerting.

The amount of additional band strain thus induced is doubtless nearly proportional to the area of contact between the staves in the straight seams. The avoidance of unnecessary thickness of

ASTORIA LINE—SHOWING PROCESS OF ERECTION.

staves, too long band spacing and the providing of such an area of contact between band and staves as shall give a necessary working compressive strain on the wood, not in excess of its permanent resisting strength, and only sufficiently below it to make certain of its not being exceeded by the water pressure ought, therefore, to commend themselves as prime essentials in avoiding unnecessary and perhaps injurious band strains.

The special advantage of a band of curved section, as contrasted with a flat band, now becomes apparent, since by the former a permanent compressive strain on the wood is provided sufficient to produce a decided indentation. The swelling of the staves, if any, and the accompanying increased compressive strains beneath the band are therefore followed by a farther yielding of the wood; and as the band strain increases, the area of contact with the band is increased by the farther indentation of the stave. With flat bands the unit compressive strain beneath them would almost invariably be so low that no indentation of the stave would result, and swelling strains to the full exerting power of the wood would be added to the band strains arising from other sources.

### TEMPORARY AND PERMANENT STRAINS.

From the foregoing it is apparent that the strains resulting on first filling a pipe, or temporory strains, the necessary strains for permanently maintaining a tight pipe under pressure, and the permanent strains finally obtaining in the pipe, are three separate and usually very different quantities.

The permanent strains in a band are evidently the sum of those induced by final cinching, by water pressure and by the transverse swelling of the staves, subject only to the limitations imposed by the sustaining and swelling power of the wood when saturated,

The band strain necessary to maintain a tight pipe has already been shown to be that requisite to resist the water pressure and to maintain any excess of pressure between the staves needed to prevent seam leaks.

The temporary strain induced on first filling is the sum of the final cinching strain, the water pressure strain, and that arising from a swelling of the staves, subject only to the limitation of the immediate compressive resistance of the wood under the band while still dry, a limit scarcely reached in any proper construction.

## STRAINS RESISTED BY STAVES.

In discussing the causes and effects of band strains, the character of the strains resisted by the staves have been made sufficiently plain. Their further influence upon proper design will be considered later.

## EQUATIONS DEDUCED.

In the following equations for the various strains previously considered, the symbols used are as follows:

R = the internal radius of the pipe.

r = the radius of the band section.

t = the thickness of the stave, in inches.

f = the spacing of the bands between centers, in inches.

S = the tensile strain in the band, in pounds.

s = the safe tensile strain in the band, in pounds.

E = the permanent sustaining power of the staves, in pounds per lineal inch of band.

E′ = the temporary sustaining power of the staves, in pounds per lineal inch of band.

E″ = the permanent swelling force of the wood, in pounds per square inch.

E‴ = the temporary swelling power of the wood, in pounds per square inch.

P = the water pressure, in pounds per square inch.

e = the safe bearing power of the wood, in pounds per lineal inch of band.

X = the additional strain induced by band cinching in pounds.

The least band strain induced by water pressure = P R f.

The permanent band strain induced by swelling of staves = f t E″.

The least permanent strain in the bands of a tight pipe = $(X + P R f + f t E'')$, $< R E$. Assuming $X = \frac{2}{3} t f P$ and substituting, we have as the least permanent value of S for a tight pipe when $P < E''$.

$$S = \left(P f (R + \tfrac{2}{3} t) + E'' t f\right), < (R + t) E \ldots\ldots (1)$$

If $P > E''$, this becomes

$$S = \left((R + \tfrac{2}{3} t) P f\right), < (R + t) E \ldots\ldots (2)$$

which is the equation generally used for computing band strains for all pressures.

The least temporary band strain induced on first filling a tight pipe $= (X + P R f + E''' t f) , < (R + t) E'$. Assuming as before, $X = \frac{3}{2} t f P$ and substituting, we have as the temporary value of S when $P < E'''$

$$S = \left(P f (R + \tfrac{3}{2} t) + E''' t f\right), < (R + t) E' \ldots\ldots\ldots (3)$$

If $P > E'''$, the equation becomes the same as (2).

From the foregoing the following equations, convenient for application, are deduced:

When $P < E''$:

$$f = \frac{s}{(R + \frac{3}{2} t) P + E'' t}, \text{ when } s < (R + t) e - (A)$$

$$f = \frac{(R + t) e}{(R + \frac{3}{2} t) P + E'' t}, \text{ when } s > (R + t) e - (B)$$

When $P > E''$

$$f = \frac{s}{(R + \frac{3}{2} t) P}, \text{ when } s < (R + t) e - (C)$$

$$f = \frac{(R + t) e}{(R + \frac{3}{2} t) P}, \text{ when } s > (R + t) e - (D)$$

Inasmuch as stave pipe has never been used under heads where the value of P is greater than E'', and since, as will subsequently be seen, it has not as great economic value under such heavy pressures as under lighter pressures, formulas (C) and (D) have no great practical value.

## SUSTAINING AND SWELLING POWER OF STAVES.

In order to make use of the formulas, it is essential that proper values be determined for E, E', E'', E''' and e.

Since the sustaining power of wood depends upon the degree of its permissible compression within the limit of its ultimate crushing, it is necessary to assume some fixed amount of stave indentation as a basis for determining the probable values of E and E'. Now in the actual process of pipe construction, it has been frequently observed that an indentation equal to one-eighth of the radius of a round band, of such sizes as other considerations render suitable for use, may be produced in the stave without breaking the fiber,

while any considerable increase beyond this point has a destructive effect. This degree of indentation gives a bearing surface equal to half the diameter of the band, which may therefore be assumed as the greatest that can be safely obtained.

In considering contact between cylindrical bodies and the flat surfaces of saturated timber, the ordinary experimental data relating to flat surfaces having uniform contact with seasoned timber are scarcely applicable. The scarcity of experiments influencing the correct determination of these values is to be regretted, and it is hoped will yet be supplied.

So far as the author is aware, the only experiments available are those made by D. C. Henny, M. Am. Soc. C. E. A study of these experiments forecast some interesting conclusions regarding these values, and additional light is derived from a study of the strains prevailing in some existing pipe lines, as will be shown later. The experiments mentioned were made to determine the swelling power of Oregon "yellow fir." For convenience, the results are here reproduced:

TABLE NO. 1..

| Date of Immersion. | Date of Observation. | Observed Strain in Bands, in Pounds. | Corresponding Strain per Square Inch Between Staves. | Corresponding Strain on Staves under Band per Lineal Inch of Band. | Corresponding Strain on Staves under Band per Square Inch of Contact. | Remarks. |
|---|---|---|---|---|---|---|
| | | | SECTION 1, No. 1. | | | |
| Feb. 27 | Feb. 27 | 4,750 | 288 | 456 | 1,830 | Initial strain before submerging. |
| | Mch. 1 | 3,400 | 206 | 328 | 1,310 | |
| | " 4 | 2,950 | 179 | 284 | 1,140 | |
| | " 7 | 2,750 | 167 | 265 | 1,060 | |
| | " 9 | 2,525 | 153 | 243 | 970 | |
| | " 12 | 2,525 | 153 | 243 | 970 | |
| | | | SECTION 1, No. 2. | | | |
| | Mch. 12 | 100 | 7 | 10 | 38 | Band was loosened to the strain indicated. |
| | " 18 | 1,500 | 91 | 145 | 580 | |
| | " 21 | 1,500 | 91 | 145 | 580 | |
| | " 26 | 1,550 | 94 | 150 | 600 | |

Section 1, No. 3.

| | | | | | | |
|---|---|---|---|---|---|---|
| | Mch. 26 | 500 | 30 | 48 | 190 | Band again loosened to strain indicated. |
| | Apl. 1 | 1,000 | 61 | 97 | 390 | |
| | " 4 | 1,050 | 64 | 101 | 400 | |
| | " 8 | 1,100 | 67 | 106 | 420 | |
| | " 11 | 1,200 | 73 | 116 | 460 | |
| | " 15 | 1,225 | 74 | 118 | 470 | |

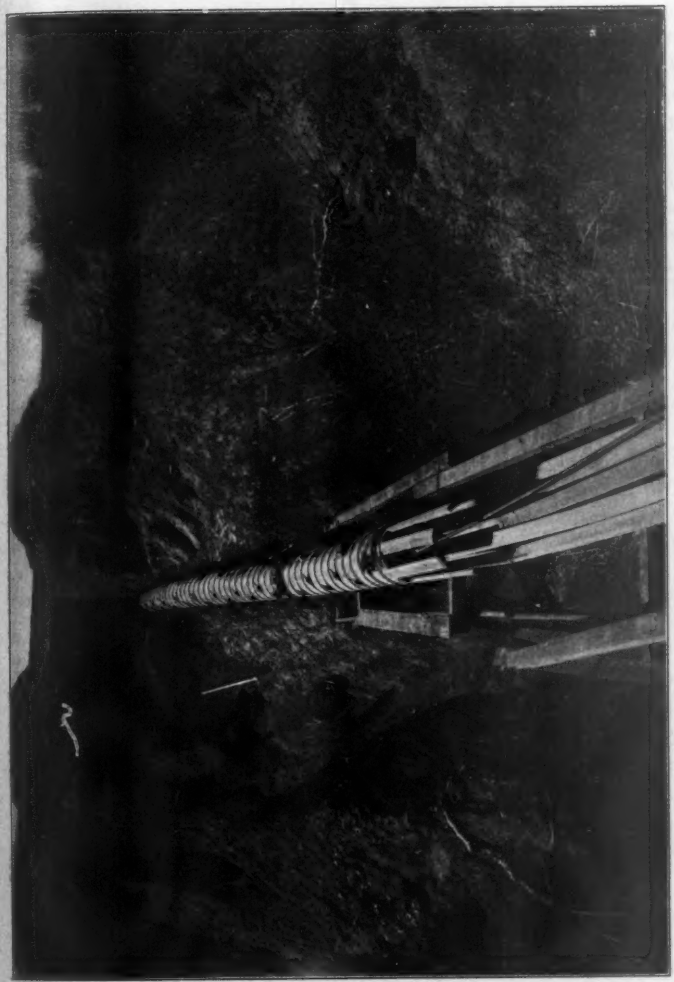
Section 2, No. 1.

| | | | | | | |
|---|---|---|---|---|---|---|
| Apl. 16 | Apl. 16 | 450 | 33 | 43 | 170 | Band was first drawn to tension of 5000 pounds and then released to the strain indicated. |
| | " 17 | 1,400 | 85 | 135 | 540 | |
| | " 20 | 1,900 | 115 | 183 | 730 | |
| | " 24 | 2,000 | 121 | 192 | 770 | |
| | " 27 | 1,975 | 120 | 190 | 760 | |
| | May 1 | 1,900 | 115 | 183 | 730 | |
| | " 4 | 1,900 | 115 | 183 | 730 | |
| | " 7 | 1,800 | 109 | 173 | 690 | |
| | " 10 | 1,700 | 103 | 164 | 660 | |
| | " 13 | 1,600 | 97 | 154 | 620 | |
| | " 17 | 1,600 | 97 | 154 | 620 | |

In these experiments the bands were depressed into the staves until a bearing of half their diameter was secured.

In experiment No. 1, with Section 1, it will be noted that a very heavy initial tension was put upon the band, which the staves, after being immersed, could no longer withstand. The resulting compressive strain resisted by the staves under the bands accordingly fell from 456 pounds per lineal inch of band to 243 pounds, or 970 pounds per square inch of contact, at which point it became stationary, although, the staves being at this stage probably incompletely saturated, a longer immersion might have resulted in producing a slightly lower permanent resistance. The result is strongly indicative that this pressure of 970 pounds per square inch of contact is the utmost that in practice can be permanently resisted by the staves, while the subsequent experiments show that hard cinching and a full band bearing as here used are necessary to secure nearly so high a resistance. As will be noticed later, the correctness of this general deduction is practically substantiated by a study of some existing structures.

The resulting compression between the staves in this experiment is seen to be 153 pounds per square inch, a figure from which no conclusion can be drawn other than that the diminution in the band



14-in. Soldiers' Home Extension—West Los Angeles Water Co., During Construction.

strain must have been the result of yielding under the band rather than between the staves.

Experiments Nos. 2 and 3, with the same section, in which the band tension was successively released by means of the wrench, are evidently well calculated to determine the approximate swelling force exerted laterally by the staves. The staves having been compressed for a period of two weeks, to a degree under the bands well beyond the limit of the wood's elasticity, it is evident that a very slight lengthening of the band by unscrewing the nut would be immediately followed by the partial or entire release of the band strain. The amount of lengthening necessary for this result would doubtless be but a small fraction of the total, say 3 per cent. expansion by swelling, of which the kiln-dried timber would be capable if unresisted. The staves, not having been compressed laterally in the previous experiment to a degree in any way calculated to impair their swelling power, were then free to develop this power to the utmost within the limit of their ultimate bearing power under the bands, which the previous experiment has shown to be not less than 970 pounds per square inch of contact. On the first release of the band strain, No. 2, the staves developed a swelling power of 94 pounds per square inch. On the second release, they developed a power of 74 pounds per square inch, the power dininishing as might be expected as the wood gradually approached its full unrestrained proportions.

The experiment with Section 2 is a confirmation of the results derived from experiment 2 on Section 1. The pipe was but slightly cinched after the band had been brought to a proper bearing. The staves developed a swelling power of 97 pounds per square inch, a figure almost identical with that given by the previous experiment, while the resulting compressive strain under the band, 620 pounds per square inch, was not such under the prevailing conditions as to be likely to cause a degree of yield which would vitiate the result.

So far as they go, these experiments demonstrate: (1) That with a proper degree of compression, an ultimate permanent pressure of between 900 and 1,000 pounds per square inch of contact with the band may be resisted by the staves. This result may probably be conservatively assumed to obtain in the use of all bands of prevailing sizes, and of staves without regard to the character of the grain. (2) That the ultimate swelling power of the wood may be taken at

from 90 pounds to 100 pounds per square inch of stave contact in straight seams, a result which may be effected by the spacing of the bands, since a slight flexure in the stave would tend to release the strain instead of transmitting it to the bands. (3) That for water pressures exceeding say 94 pounds per square inch, and probably considerably less, hard cinching rather than the swelling of the wood must be relied upon to maintain a tight pipe. (4) That the yielding quality of the wood renders hard cinching not seriously objectionable in its effect upon final band strains with the usual factors of safety in the band and when working reasonably close to the limit of ultimate compressive resistance of the stave.

As it has been observed in practice that the difference in the compressive strength of Douglass fir and redwood is not very great when both are saturated, for the present purposes no distinction will be made between them.

One of the most important points to be determined from the foregoing is the maximum value for e which can be used with entire safety in designing a pressure pipe. It will be shown later that pressures as high as 1,100 pounds per square inch have been successfully used under favorable conditions, but the logical conclusions drawn from the previous discussion, as well as some results from actual experience given later, strongly indicate that such an assumption is insufficiently conservative for entirely safe construction. With thorough compression of the bands into the staves, well-seasoned lumber, skilled construction and entire immunity from water-hammer, it would seem that this value should not be taken much if any above 800 pounds per square inch, while if subject to any considerable fluctuations of pressure or to doubtful constructive skill, a much lower figure should be used.

In view of the foregoing the following values are assigned for use in the formulas previously given:

$E = 240$ pounds for $\frac{1}{2}$ inch bands, when the fiber is fully compressed (960 pounds per square inch).

$E' =$ say 500 pounds, in the absence of any experiment.

$E'' = 95$ pounds for 12-inch band spacing. Assumed at 100 pounds for all spacings.

$E''$ = 120 pounds for 12-inch spacing. Assumed at 125 pounds for all spacings.

e = equivalent of 800 pounds per square inch of band contact or less.

DETERMINATION OF THE PROPER SIZE AND FORM OF BAND.

Before making use of any formula for the determination of proper band spacings, it is necessary to determine the size and form of section of the band that will most economically fulfill the requirements of any particular case in hand. The selection will be influenced by the following considerations: Bands less than ⅜-inch in diameter are not suitable for use chiefly because of torsional weakness and difficulty of upsetting. An increase in the permissible value of e may be obtained without increase of metal section of band by using an oval form, which can be obtained at only a slight increase of cost above the rounds of similar weight. The price per pound for the bands is less for the heavier than the light sections. The use of upset rods or rolled threads is always economical, the latter being usually preferable because of the more perfect workmanship. The heavier the bands used, the fewer to be handled, the less the cost for both material and labor and the better the condition of the band section for resisting corrosion, though the added stiffness, increasing the difficulty of placing, will in the larger sizes partially offset these advantages.

Referring to the formulas for band spacing, it is seen that economy in the use of the steel requires the selection of a band of such sectional area that if possible $s < (R + t)\,e$, as otherwise it is necessary to use closer spacing—more steel than the pressure requires, in order to secure a sufficiently low value for e.

By writing $s = (R + t)\,e$, the greatest value of s for any given band section that can be used consistently with a desired value of e, may be determined; and by substituting for s and e their proper values corresponding to bands of various standard sizes, the limitations of the economic use of each may be ascertained, thus:

$$R + t = \frac{s}{e}$$

TABLE No. 2.—MINIMUM SIZES OF PIPE TO WHICH SPECIFIED BANDS ARE APPLICABLE WITHOUT EXCEEDING VALUES OF 650 LBS. AND 750 LBS. FOR e, AND A FACTOR OF 4 FOR THE BANDS.

| Size of band. | s (=¼ ultimate strength.) | Band pressure per square inch. | e (Band pressure per lineal inch.) | Least external radius of pipe. | Band pressure per square inch. | e (Band pressure per lineal inch.) | Least external radius of pipe. |
|---|---|---|---|---|---|---|---|
| in. | lbs. | lbs. | lbs. | in. | lbs. | lbs. | in. |
| ⅜ | 1,650 | 650 | 122 | 13.5 | 750 | 140 | 11.8 |
| 7/16 | 2,250 | 650 | 142 | 15.8 | 750 | 164 | 13.7 |
| ½ | 2,950 | 650 | 163 | 18.1 | 750 | 187 | 15.7 |
| 9/16 | 3,725 | 650 | 183 | 20.4 | 750 | 211 | 17.65 |
| ⅝ | 4.600 | 650 | 203 | 22 6 | 750 | 234 | 19.6 |
| ¾ | 6,600 | 650 | 244 | 27.0 | 750 | 281 | 23.5 |

A factor greater than 4 must therefore be used in the steel in designing pipes of smaller diameter, if bands of round section are used, and the specified values of e are not exceeded. The band strains to be used are readily determined by the same formula as before indicated:

$$s = (R + t)\, e.$$

By the use of a band of oval section, a greater bearing surface is secured between the band and the staves with the same degree of indentation, thus permitting the use of less steel for given values of e, in designing pipes of smaller diameter. For this reason they have been already introduced and used by the Excelsior Wooden Pipe Company of San Francisco, on a number of pipe lines, though not with the economy that would now attend their use, as manufacturers have not until recently been able to quote the present figures which are but little in excess of the price for rounds. These conditions will doubtless lead to the general use of the oval section on small pipes, though any departure from the round sections has the disadvantage of exposing a greater relative surface to corrosive action.

TABLE NO. 3.—GREATEST BAND STRAINS CONSISTENT WITH SPECIFIED VALUES OF e FOR PIPES OF SMALL DIAMETER.

$\frac{3}{8}$-in. Round Bands.

| Internal Diameter of Pipe. | External Radius of Pipe. | s (=Assumed Working Strains in Band.) | Factor of Safety in Band. | s (=Assumed Working Strain in Band.) | Factor of Safety in Band. |
|---|---|---|---|---|---|
| e = 122 lbs. = 650 per square inch. | | | | e = 140 lbs. = 750 lbs. per square inch. | |
| 12 ins. | 7.1 | 866 | 7 6 | 994 lbs. | 6.1 |
| 16 " | 9.2 | 1,122 | 5.9 | 1,288 " | 5 1 |
| 20 " | 11.2 | 1,366 | 4.8 | 1,568 " | 4.2 |
| 24 " | 13.5 | 1,650 | 4.0 | | |

The use of an oval section in the above cases would result in the saving of about 17 per cent. of the steel.

BAND SPACING.

If, in accordance with the foregoing, the proper band is determined for a pipe of given diameter, formulas A, B, C or D, may at once be applied to determine the proper spacing for any pressure and thickness of stave, the selection for any case being made by observing the relative values first of P and E, and then of s and (R+t)e as indicated.

REQUISITE THICKNESS OF STAVES.

The staves must be thick enough to prevent percolation, to resist undue flexure with the band spacing adopted, to prevent cracking or crushing of quarter sawed staves during the process of cinching and to afford the rigidity necessary to support the weight of the pipe and backfilling without distortion. With these requirements met, the staves, for reasons already mentioned, should be as thin as possible.

Concerning percolation through the staves, in using Douglass fir under pressures in excess of about 80 feet, vertical and bastard grained staves only should be used if the staves are $1\frac{3}{8}$ inches in thickness. With this precaution, trouble will not arise from the splitting of quarter sawed staves, and this thickness will be found sufficient to resist percolation at any pressure under which

stave pipe is likely to be used. Redwood being of finer grain gives no trouble from percolation.

If the size of band for a pipe of any diameter, and the band spacings are determined in accordance with the foregoing principles, staves of the thicknesses generally used will always be safe against undue flexure if a maximum spacing of 12 inches is adopted. This is by no means an extravagant assumption, since this spacing will, in most cases, correspond to a very light water pressure; and if when designing a pipe of large diameter the band selected gives an unnecessarily large factor under light heads with this spacing, a smaller band can be substituted.

A practical consideration that has influenced very properly the thickness of staves, is the desirability of running them from timbers of commercial sizes. Thus by enabling the mill to dispose of rejected pieces, a lower price on the accepted staves is secured.

The practice of running staves from 2 inches x 6 inches, 2 inches x 8 inches and 3 inches x 8 inches stock nearly meets the economic requirements of pipes designed in accordance with the foregoing principles, which requirements will, however, be a little better conserved if 1½ inches x 4 inches is used for the smallest diameters, and if the odd size 2½ inches x 8 inches is used for certain sizes of pipes intermediate between those for which 2 inches x 6 inches and 3 inches x 8 inches are used.

A careful study of these and other requirements points to the following as being for general use the best balance between the various influences affecting the relation between pipe diameters and the size of stock for staves, the staves in each case being run as thick as the stock will permit.

| Pipe Diameters. | Stock Sizes. |
|---|---|
| 10 ins. to 14 ins. | 1½ ins. x 4 ins. |
| 16 " " 48 " | 2 " x 6 " |
| 50 " " 58 " | 2½ " x 8 " |
| 60 " " 72 " | 3 " x 8 " |

## SUGGESTED STANDARD DESIGNS.

Assigning to e the conservative value of $\frac{660}{r}$, the author ventures to submit the following table of pipe diameters, with the corresponding stave thicknesses and character of bands, which, for the conditions of general use, he believes to be as closely in accord

with sound theory and economic practice as the present state of investigation and the constructive art will permit. The economy of these relative proportions is somewhat influenced by the locality of construction as affecting freight rates on the steel, but not to a serious extent. Should it be desired to use some other value of e than that designated, the needed modification can be made without difficulty.

TABLE NO. 4.—ECONOMIC PROPORTIONS FOR PIPE DESIGNS.

| Nominal Diameter. | Stock Sizes for Staves. | Thickness of Finished Staves. | Economic Sizes of Bands. | s (Permanent Band Strain,) | Factor Safety in Band. | e (Maximum Values $= \frac{650}{r.}$) |
|---|---|---|---|---|---|---|
| Inches. | | | | Lbs. | | Lbs. |
| 10 | 1½ ins. x 4 ins. | 1 1/16 ins. | 5/16 x 7/16 | 1,255 | 5.26 | 207 |
| 12 | 1½ " x 4 " | 1 1/16 " | " " | 1,475 | 4.47 | 207 |
| 14 | 1½ " x 4 " | 1 3/16 " | " " | 1,650 | 4 | . . |
| 16 | 2 " x 6 " | 1 7/16 " | " " | 1,650 | 4 | . . . |
| 18 | 2 " x 6 " | 1 5/8 " | " " | 1,650 | 4 | . . . |
| 20 | 2 " x 6 " | 1 13/16 " | " " | 1,650 | 4 | . . . |
| 22 | 2 " x 6 " | 1 15/16 " | 3/8 | 1,508 | 4.4 | 122 |
| 24 | 2 " x 6 " | 1 15/16 " | " | 1,650 | 4 | . . . |
| 27 | 2 " x 6 " | 1 7/16 " | " | 1,650 | 4 | . . . |
| 30 | 2 " x 6 " | 1½ " | ½ | 2,673 | 4.4 | 162 |
| 36 | 2 " x 6 " | 1 9/16 " | ½ | 2,950 | 4 | . . . |
| 42 | 2 " x 6 " | 1 11/16 " | ½ | 2,950 | 4 | . . . |
| 48 | 2 " x 6 " | 1 13/16 " | ½ | 2,950 | 4 | . . . |
| 54 | 2½ " x 8 " | 2 1/16 " | " | 4,600 | 4 | . . . |
| 60 | 3 " x 8 " | 2½ " | " | 4,600 | 4 | . . . |
| 66 | 3 " x 8 " | 2 9/16 " | ¾ | 6,600 | 4 | . . . |
| 72 | 3 " x 8 " | 2 5/8 " | " | 6,600 | 4 | . . . |

SOME EXISTING PIPE LINES.

In seeking data concerning pipe lines already constructed, the author has encountered the customary indifference or unwillingness on the part of many engineers to divulge anything pertaining to the methods used in the design and execution of the work done under their supervision. Especially has this been the case where defects of a serious nature have developed. This is of course a matter for regret, since the most instructive deductions can usually be made from such experiences. Chief among the works which

might well be made instructive to the profession, but which for the above reasons is necessarily here omitted, is the 36-inch and 38-inch outfall sewer of the City of Los Angeles, Cal.

On the other hand, the author wishes to express his grateful recognition of the courtesies extended by those engineers whose appreciation of the advantage to the profession arising from a general discussion of engineering subjects by engineers has largely made possible the preparation of this paper.

From the many existing lines of stave pipe, thirteen have been selected for presentation. These, it will be observed, cover a great range in both size and pressure, and are, with some exceptions, characteristic of the best practice prevailing at the time of their construction. There would be little gained by pointing out defects in design of a nature that would be patent to any intelligent person, for which reason no cognizance is taken of any existing pipes that have been designed or constructed foolishly.

Table No. 5 is believed to be self-explanatory in the light of the previous discussion. The chief interest centers in the unit band strains used, the probable effect upon these of the swelling of the staves, and the necessary compressive resistance of the staves. Of the latter, it is of course the maxima that are chiefly interesting, and these for reasons already made plain are usually found in pipes of relatively small diameter, since with large pipes other considerations lead to lower values.

## BAND STRAINS.

The factors used in proportioning the spacing of the bands, disregarding the strains induced by swelling timber, vary from 1.64 to 10.45, while the factors resulting from a consideration of the stave swelling range from 1.30 to 4.35. This latter source of strain seems to have received no recognition in design previous to 1895. Since then, in the design of the Los Angeles, Astoria, Hollister and West Los Angeles lines, a modification of the band spacings has been made for the lighter pressures in recognition of this strain, it being however ignored where spacings became less than 8 or 9 inches. On the St. Paul line, while it is not clear what general assumptions have governed the determination of the band spacings, the factors used indicate some recognition of these strains.

TABLE NO. 5.—STRAINS IN SOME EXISTING PIPE LINES.

| | Location of pipe. | Date of construction. | Nominal diameters, in inches. | Length in miles. | Thickness of staves in inches. | Kind of wood. | Character of round bands. | Ultimate strength of bands. | Maximum band spacing, in inches. | Feet pressure for maximum spacing. | Minimum band spacing in inches. | Feet pressure, for minimum spacing. | Band strain from water pressure. | Band strain from least practicable circbnlr. | Resulting band factor, neglecting strain from swelling staves. | Band strain from swelling staves. | Resulting factor in band, including all strains. | Least band pressure on staves per linear inch, to maintain tight pipe. | Least band pressure on staves per square inch, to maintain tight pipe. | Total probable band pressure on staves, per linear inch of band. | Total probable band pressure on staves, per square inch on band contact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Denver, Colo | 1889 | 30 | 18.00 | 1⅛ | ..... | 1¼ in. upset | 11 800 | 12 (?) | 32 | .... | 172 | 2 500 | 698 | 3.90 | 3 010 | 2.34 | 162 | 729 | 303 | 1 212 |
| | " " | | | | | ..... | | | | | | | 2 500 | 698 | 3.90 | 373 | 3.46 | 182 | 729 | 205 | 820 |
| 2 | Provo, Utah | 1891 | 14 | 3.70 | 1⅛ | Redwood. | ⅞ in. plain. | 5 800 | 18 | 25 | .... | 166 | 1 367 | 402 | 3.00 | .... | .... | 211 | 1 126 | .... | .... |
| | " " | | | | | ..... | | | | | | | 1 944 | 396 | 3.00 | 378 | 2.50 | 208 | 1 108 | 253 | 1 349 |
| 3 | Caldwell, Idaho | 1890 | 54 | 0.13 | 1⅛ | Pine | ½ in plain | 6 300 | .... | .... | .... | 50 | 3 515 | 327 | 1.64 | 1 095 | 1.30 | 134 | 536 | 169 | 676 |
| 4 | Butte, Mont | 1892 | 24 | 9.00 | 1 7-16 | Redwood. | ⅝ in. upset | .... | 6 | 82 | .... | .... | 2 562 | 461 | 3.9 | 861 | 3.04 | 225 | 900 | 289 | 1 156 |
| | " " | | | | | ..... | | | | | .... | 202 | 2 562 | 461 | 3.9 | 351 | 3.50 | 225 | 900 | 291 | 1 004 |
| 5 | Bear Valley, Cal | 1893 | 52 | 0.41 | 2.00 | Redwood. | ⅞ in. upset. | 17 200 | 12 | 28 | .... | 165 | 3 791 | 497 | 4.06 | 2 400 | 2.60 | 151 | 483 | 236 | 787 |
| | " " | | | | 2.60 | ..... | | | | | .... | .... | 3 724 | 558 | 4.00 | 520 | 3.58 | 150 | 479 | 195 | 837 |
| 6 | Logan, Utah | 1893 | 18 | 1.00 | 1 7-16 | Redwood. | ⅞ in. plain | 5 300 | 12 | 18 | .... | .... | 844 | 203 | 5.08 | 1 728 | 1.91 | 100 | 533 | 266 | 1 417 |
| | " " | | | | | ..... | | | | | 4.00 | 63 | 828 | 200 | 5.08 | 876 | 3.30 | 99 | 525 | 194 | 826 |
| 7 | Los Angeles, Cal | 1895 | 24 | 1.00 | 1⅛ | Redwood. | * .... .... | 9 000 | 12 | 25 | .... | .... | 1 502 | 289 | 4.92 | 1 050 | 2.58 | 137 | 414 | 260 | 785 |
| | " " | | | | | ..... | | | | | 4.00 | 88 | 1 833 | 315 | 4.20 | 550 | 3.34 | 161 | 486 | 202 | 610 |
| 8 | Astoria, Ore | 1895 | 18 | 7.50 | 1⅛ | Fir | 7-16 in. upset | 9 000 | 12 | 25 | .... | 175 | 1 166 | 269 | 5.66 | 1 650 | 2.75 | 138 | 631 | 297 | 1 308 |
| | " " | | | | | ..... | | | | | 2.25 | .... | 1 538 | 353 | 4.76 | 309 | 4.10 | 182 | 833 | 212 | 970 |
| 9 | Hollister, Cal | 1896 | 12 | .... | 1⅛ | Redwood. | ⅞ in. rolled thread | 6 600 | 10 | 23 | .... | .... | 599 | 149 | 8.59 | 1 125 | 3.48 | 108 | 575 | 266 | 1 417 |
| | " " | | | | | ..... | | | | | 2.75 | 100 | 716 | 201 | 7.20 | 309 | 5.38 | 129 | 686 | 172 | 918 |
| | " " | | 14 | .... | 1 6-32 | ..... | ⅞ in. rolled thread. | .... | 11 | 22 | .... | .... | 735 | 182 | 7.20 | 1 272 | 3.01 | 112 | 600 | 268 | 1 430 |
| 10 | St. Paul, Minn | 1896 | 42 | 1.60 | 1⅛ | Fir | ½ in. plain. | 7 500 | 14 | 5 | .... | .... | 835 | 207 | 6.33 | 318 | 4.85 | 128 | 680 | 167 | 889 |
| | " " | | | | | ..... | | | | | 2.75 | 100 | 638 | 80 | 10.45 | 2 450 | 2.36 | 32 | 128 | 141 | 563 |
| 11 | W. Los Angeles, Cal | 1896 | 30 | 7.60 | 1⅛ | Redwood. | ⅞ in. rolled thread. | 11 800 | 12 | 20 | .... | .... | 1 562 | 276 | 6.42 | 1 800 | 3.25 | 111 | 446 | 220 | 863 |
| | " " | | | | | ..... | | | | | 4.00 | 25 | 911 | 114 | 7.32 | 700 | 4.35 | 46 | 182 | 77 | 306 |
| | W. Los Angeles, Cal | | | | | ..... | | | | | | | | | | | | | | | |
| 12 | Ogden, Utah | 1897 | 72 | 6.10 | 2.00 | Fir | ⅞ in. upset. | 18 400 | 5.25 | 55 | 3.50 | 105 | 2 370 | 355 | 4.33 | 520 | 3.63 | 165 | 660 | 197 | 788 |
| | " " | | | | | ..... | | | | | .... | .... | 4 490 | 374 | 3.78 | 1 060 | 3.11 | 128 | 509 | 156 | 467 |
| | " " | | | | | ..... | | 26 400 | .... | .... | 2.875 | 100 | 4 490 | 374 | 3.78 | 570 | 3.38 | 128 | 509 | 143 | 447 |
| | " " | | | | | ..... | | | | | 3.64 | 117 | 6 471 | 539 | 3.77 | 708 | 3.42 | 184 | 492 | 170 | 464 |
| 13 | W. Los Angeles, Cal | 1896 | 14 | 7.50 | 1⅛ | Redwood. | ⅞ in. rolled thread. | 5 500 | 10 | 20 | .... | .... | 605 | 194 | 6.88 | 1 125 | 2.81 | 98 | 524 | 237 | 1 264 |
| | West Los Angeles, Cal | | | | | ..... | | | | | | | | | | | | | | | |
| | | | | | | | | | | | 4.50 | 66 | 898 | 217 | 4.93 | 506 | 3.40 | 137 | 730 | 166 | 885 |

* Oval bands, ⅞ in. x ¼ in., were used.

Any estimate of the strains due to the swelling of the staves under the maximum band spacing on the Provo line has been omitted. With the spacing of 18 inches under a water pressure of 25 feet, a stave 1⅜ inches in thickness, a pressure of 211 pounds per lineal inch of band on the stave and a lack of hard cinching during construction, it is doubtful if such a strain exists to a considerable extent.

The Caldwell or Phillis pipe was a bold design as originally built, and is the only instance known to the author where pipe bands were actually broken by the swelling of the staves. The lumber used was Eastern Oregon mountain pine. A factor of only 1.64 seems to have been used in the spacing. On the assumption that stave swelling produces a strain of 100 pounds per square inch of contact between staves, doubtless a very conservative assumption with this class of lumber and size of pipe, and with 6-inch band spacing, this band factor would be reduced to 1.30. Uncertainty as to the exact tensile strength of the material used, and the use of a shoe of the type shown in figure 4 with the probable resulting bending of the band under the nuts, is doubtless sufficient to account for the rupture of the bands. The pipe being of large diameter, the pressure of the bands upon the staves is seen to have been too low to admit of any further yielding and consequent partial release of the band strain.

The difficulty with this pipe is said to have been remedied by largely increasing the number of bands.

### COMPRESSIVE RESISTANCE OF STAVES.

The highest degree of compressive strain between band and staves necessary for the maintenance of a tight pipe seems to have been used at Provo, and the results are instructive. The ready stripping of threads due to poorly fitting nuts, prevented very hard cinching and satisfactory compression of the staves under the band. The timber was seasoned redwood. The pipe, a gravity line, is closed at the end, feeding direct into the distributing system. The use of hydrants for street sprinkling and other purposes caused a water pressure at the lower end of the line of 30 pounds above the normal, making the pressure on the staves 290 pounds per lineal inch of band under these conditions or 1,550 pounds per square inch of band contact. Leakage resulted, which was remedied by

the addition of more bands, the re-cinching of those already on, and the partial prevention of the water hammer. The upper section of the pipe, not being subject to any considerable increase of pressure over that for which it was banded, has never given any trouble, although as seen in Table No. 5 the normal pressure on the staves cannot be much less than 211 pounds per lineal inch of band, or 1,126 pounds per square inch of band contact.

On the Butte line the staves are depended upon to afford a permanent resistance against band pressure of not less than 900 pounds per square inch of band contact. At Astoria the fir staves must resist a pressure of not less than 832 pounds per square inch of band contact. Both of these lines have been successful, and the latter line especially has from the first been remarkably free from leakage. The former, by reason of the yet uncompleted condition of the storage dam which impounds the water from which the pipe is supplied, has not as yet been subjected to quite all the pressure for which it is designed.

In the smaller pipes subsequently built at Hollister, it will be noticed that much additional steel has been used in order to secure greater area of contact between bands and staves and thus keep the necessary compressive resistance of the staves down to from 600 pounds to 686 pounds per square inch. At the present time the same results might be achieved at considerably less cost by the use of bands of oval instead of round section. Such a course, as tending toward conservatism in a matter still somewhat imperfectly understood, and to partially nullify the effects of any lack of skill in erection, the author believes to be advisable in the design of the smaller sized pipes.

## CONSTRUCTION DETAILS.

There are but few structural details of this class of pipe in which there is sufficient diversity of practice to warrant any discussion. The butt-joint connection, the use or omission of a bead along one edge of the stave and the coupling shoes are the only features which need to be considered.

### BUTT JOINTS.

It is the prevailing practice to make the connection between the butts of connecting staves by the snug insertion of a No. 12 or

No. 14 steel plate about 1½ inches in width, and slightly longer than the width of the stave where inserted, the plate extending slightly less than half its width into each stave. For this, in some light pressure pipes, a plate of hard wood has been substituted. The objection to the latter lies chiefly in the difficulty of forcing a thick wooden plate into the adjoining stave sufficiently to secure a tight joint, and in securing the perfect fit evidently necessary. The existing general preference for the steel plate seems justified.

### PLAIN VS. BEADED EDGES.

The use of a bead on the stave is in no way vital to the success of a pipe, but seems to have strong points in its favor. If there is any irregularity in the edge of the plain stave, with band spacing suitable for light or moderate pressures, it is not possible and certainly not economical to induce sufficient fiber compression between the staves to take up those irregularities. By the use of a slight bead the compression due to cinching is at first concentrated on the bead forcing it into the adjoining stave, and thus a uniformly tight seam is secured without the necessity for hard compression throughout the entire contact area that exists in the other case. Furthermore the bead adds nothing to the cost of the stave.

### COUPLING SHOES.

Not a little ingenuity has been displayed in devising various types of coupling shoes, the desideratum being that with the least cost the shoe should have an ultimate strength fully equal to that of the band, a sufficient and properly distributed bearing surface to withstand high strains without destructive crushing of the stave, and admit of speedy placing and the ready adjustment of the band during erection.

In the following discussion only those types are considered which have separate characteristics, are the better of those that have been employed, and which have already met, or promise to receive, the greatest measure of favor.

The various devices in use may be divided, with reference to the manner of engaging the two ends of the band, into two general classes:

(1) Those which engage the two ends in the same transverse plane as Figs. 1, 2 and 3.

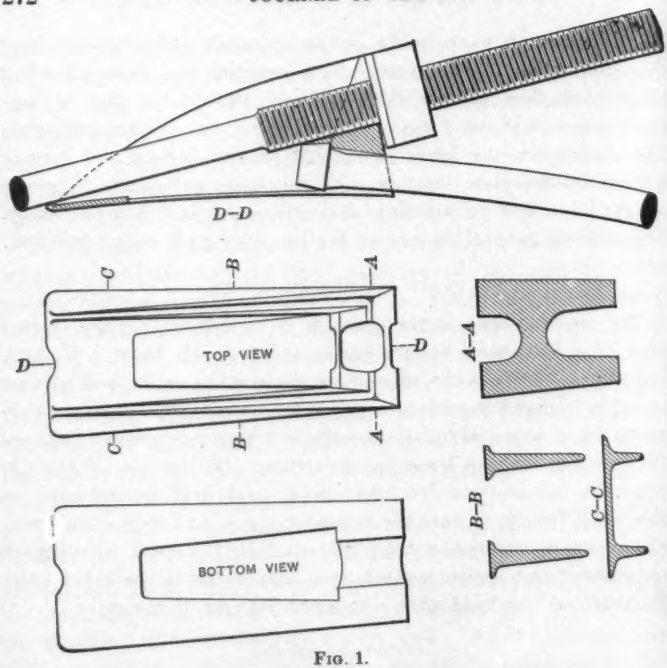

D–D
C
B
A
D
TOP VIEW
D
C
B
A
A–A
B–B
C–C
BOTTOM VIEW

FIG. 1.

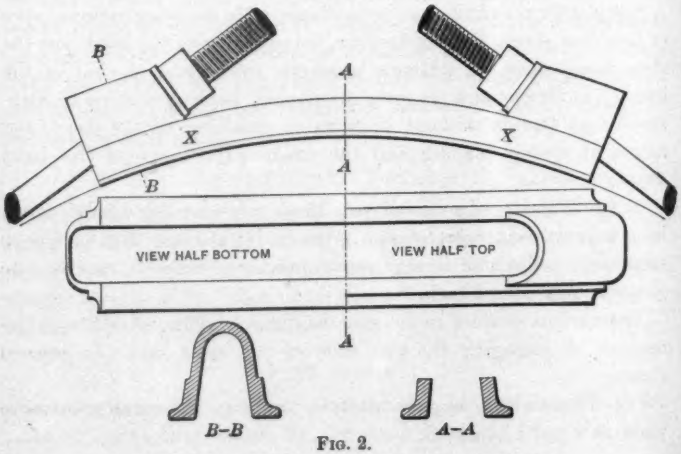

B
A
X
X
A
B
VIEW HALF BOTTOM
VIEW HALF TOP
A
B–B
A–A

FIG. 2.

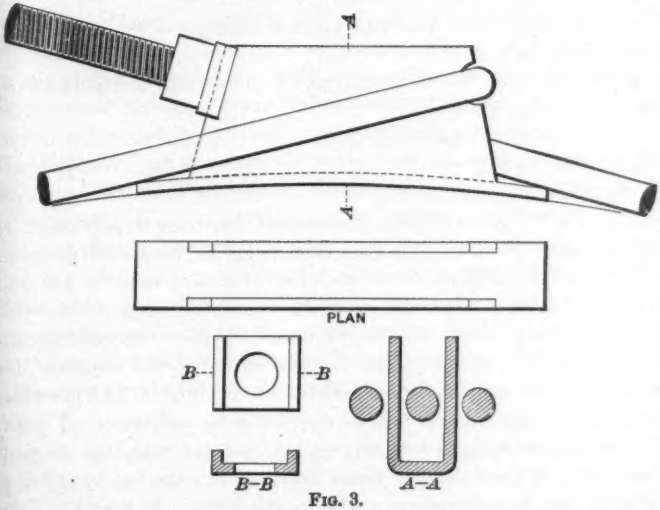



FIG. 3.

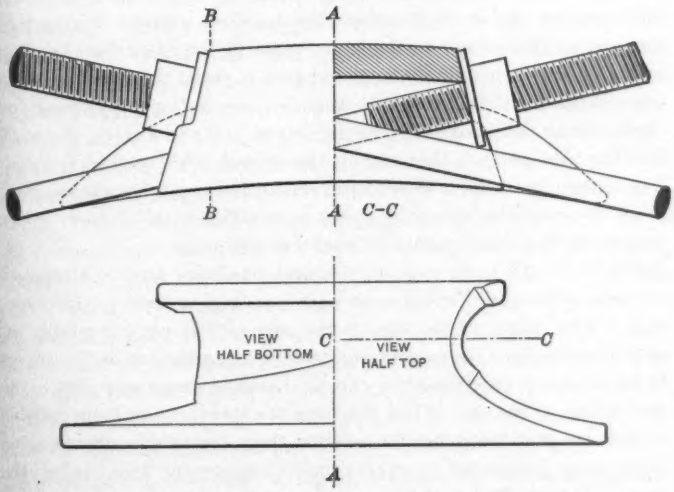



FIG. 4.

(2) Those in which the ends are not engaged in the same transverse plane, as Fig. 4.

With reference to the materials of which they are made, they may be divided into:

(1) Forged, as Figs. 2 and 3.

(2) Cast, as Fig. 4.

(3) Malleable cast, as Fig. 1.

Fig. 1 is the general form of shoe that has been largely used by the Excelsior Wooden Pipe Company, it having been evolved from, and being representative of, the type originally used in the construction of the Denver lines. When properly proportioned this shoe admirably meets all the requirements for a successful connection, and in the economical distribution of the material for resisting the strains imposed leaves little to be desired, and possesses much to be admired. It will be noted that by the use of a T-head, the nut is brought as low as possible, and the resulting moment tending to produce rotation about the centre of the head bearing is thus reduced to a minimum. The length and ample bearing of the shoe enables the stave to resist this tendency without destructive pressure. The flanges on the lower edges of the ribs afford bearing surface and give sufficient sectional area to resist the tensile strains here existing, while in height the ribs are well proportioned for transmitting the band strain to the staves. It will also be observed that the shoe permits the use of the wrench without interference. The feature most open to criticism in the design of this shoe as generally used is the tendency to make insufficient allowance in its weight for the deterioration of such light sections.

Fig. 2 shows a shoe of a type that has been used in a number of instances on the Pacific coast. It is a forging from a rolled section. The length of the shoe in the rear of the nuts is wholly insufficient to afford the proper degree of bearing surface on the staves to safely resist the pressure; and the bending strain at x, due to the depressing of the end of the shoe into the stave, can only be resisted by the use of a much heavier section than the tensile strains alone require, or prevented by giving more supporting area under the ends. It is evident that the fault lies in the use, unavoidable here, of low connecting ribs.

Fig. 3 is a forged shoe of the type used on the recently completed works of the Pioneer Power Company at Ogden, Utah. In most

respects the form is evidently well calculated to economically resist the imposed strains; but as it necessitates the use of a welded loop on one end of the band, the shoe can scarcely compare in economy with some of the other types, unless, indeed, the relative cost is very largely influenced in its favor by royalty charges on the other shoe. The details of the loop bearing on the shoe are perhaps not beyond the suggestion of improvement, as there appears to be possible lack of stiffness, which, however, could be readily remedied by the insertion between the loop and shoe of a properly designed compression lug of cast iron. It would also appear that the cost of the entire shoe might be somewhat reduced without sacrifice in other respects by modifying the design and making it of cast or malleable cast iron, for which materials the general shape of the shoe, as affecting the strains, seems especially well suited.

Fig. 4 is of that class which does not engage the ends of the bands in the same vertical plane. There being thus introduced a cross strain or tendency to rotate about an axis vertical to the center of the shoe, it is difficult to devise a really efficient and economical design. It is usually sought to resist this tendency to rotate by means of the friction afforded by long tapering extensions at each end of the casting, as in the figure shown. This device has generally been found insufficient, hard cinching usually resulting in the breaking of the tail-piece or the rotating of the shoes and the bending of the bolts. These difficulties can, of course, be corrected by the use of very large, heavy shoes, but with a resulting cost much beyond that of other and better types. This general style of casting seems to have been the first used in stave pipe construction with round bands, and has had quite an extended application in recent years, though frequently with unsatisfactory results. The particular design shown is that adopted in the construction of the Los Angeles outfall sewer, in the spring of 1894, and in detail is the best of its class that the author has seen. Nevertheless, it was found to possess the defect inherent in the type, many having broken under even the reputed light and insufficient cinching used on that work.

In conclusion, it appears to the author that the essential requirements of a safe and economical design are much more successfully worked out in Fig. 1 than in any of the others.

## THE ECONOMY OF ITS USE.

In seeking to set forth clearly the real place of stave pipe in the economic design of pressure conduits, it is essential that the conspicuous types of pressure pipes be briefly considered in their relation to each other. The three varieties to be contrasted herein are stave, steel riveted and cast iron. Welded pipe is omitted because it occupies an intermediate position and does not affect the merits of the discussion. The comparison will be confined to the pressure range of practical stave pipe construction, say not to exceed 100 pounds per square inch, for which pressure each of the classes mentioned may be assumed to be wholly applicable.

Previous to argument, the relative standing of each, in the order of their merit with reference to the three most important qualifications, the author tabulates as follows:

| Cost. | Life. | Capacity. |
|---|---|---|
| (1) Stave. | Cast iron. | Stave. |
| (2) Steel riveted. | Stave. | Cast iron. |
| (3) Cast iron. | Steel riveted. | Steel riveted. |

If the quantity of water delivered, instead of the diameter, were made the common basis of comparison for the different pipes, the capacity would become a function of the cost, an aspect briefly considered later. For the present they will be considered separately.

## LIFE.

Passing temporarily over the question of cost and taking up that of comparative duration, it may be assumed at once that cast iron should be given the preference, not, indeed, as conclusively proven by experience, but as in every way probable, since the bands of the stave pipe, excepting perhaps in the larger sizes, can hardly be supposed to have the same degree of endurance as the thick shell of the cast pipe.

In placing steel pipe last, the author is influenced by the following considerations:

(1) That the sheet metal from which the pipe is made is of less thickness than the diameter of the stave pipe bands, a condition always existing in steel pipes subject to the comparatively light pressures here considered.

(2) That the same degree of care in securing protection of the metal can be exercised in both cases.

(3) A properly proportioned steel pipe does not eventually fail by bursting, but by the formation of rust holes and attendant leakage. The considerable multiplication of such holes soon causes a new pipe to be cheaper than the necessary repairs, even though $\frac{995}{1000}$ of the metal in the pipe may be as good as when it was laid. The life of a steel pipe may, therefore, without material error, be said to be measured by the life of its weakest spots.

(4) The life of a stave pipe is probably determined by the life of the bands; and the life of the bands is determined, not by the time necessary for the formation of local rust pits, even though they are very deep, but by the reduction of the entire band section until its ultimate strength is exceeded by the strain, say to less than one-fourth its original section. It seems clear that the time requisite to accomplish this degree of deterioration in the sections generally used, must be many times that necessary to accomplish the destruction of the average light gauge riveted pipe.

(5) Many cases on the Pacific coast might be cited where steel pipe of the lighter gauges, though carefully coated with asphalt, and apparently laid with reasonable care, have rusted through in from eighteen months to three years, and have been shortly afterwards abandoned.

(6) Should a perfect and reasonably cheap protective coating for steel ever be discovered—an improbable assumption—no single class of pipe would have much advantage over another in respect of durability.

(7) It is certainly in accord with universal engineering experience to assume that wood, under the conditions prevailing in proper stave pipe construction, is practically indestructible; and much direct evidence in harmony with this assumption has accumulated from the many instances of the use of stave and other wood pipe construction which have done service in America for from twenty to fifty years, and as far as the author knows, without an instance of failure from the decay of staves where the proper requirements were observed.

The author does not wish to be understood as intimating that steel pipe is always short lived. On the contrary, many such pipes where conditions are favorable have been doing excellent service for many years; but the exceptions are instructive, and fully vindicate the position assumed by many engineers, who for permanent

work have recognized the necessity for a considerable thickness of metal independent of the demand for a sufficient factor of safety against bursting, and who accord little favor to pipes of very light gauge.

The foregoing seems to the author to be ample justification for placing the stave pipe far in advance of the steel pipe for durability under average conditions.

## CAPACITY.

The past few years have added much to the knowledge of engineers concerning the carrying capacity of cast iron and particularly of steel riveted pipes of various diameters. The relative values of each class as economic carriers of water, are better understood than ever before. The general result of experiments on cast iron pipe has been to prove the value of the Kutter formula in showing the value of "n" to be practically a constant for any given diameter, degree of surface roughness and velocity of flow. In the case of steel riveted pipes, whether built with cylindrical or taper joints, with few exceptions the results indicate that the Kutter formula does not apply, and that for the ordinary ranges of velocities, say from 3 to 6 feet per second, for clean pipes the coefficient c in the formula $v=c\sqrt{r\ s}$ is nearly a constant for all diameters; and if the experiments on the Portland, Ore., pipes are excepted, because of inability to harmonize them with others, it is not clear that the results are much affected by variations in the thickness of the plates, within the range of ordinary usage.

These experiments, while still leaving much to be desired before attempting the formulation of any positive rules for the exact preliminary determination of the rate of flow in any given case, a result which the author believes will not be accomplished save within limits of a very narrow application, because of the usual unavoidable lack of similarity in the influencing physical conditions, are sufficient to accomplish the complete upsetting of many previously conceived ideas regarding the laws of flow in this class of pipe. The failure of "c" to increase as the diameter increases, places the value of this pipe as an efficient water carrier, at least for the large diameters, in a relation to pipes having approximately smooth interiors, totally different from that which it has previously been accorded.

The dissipation of the once prevalent idea that wrought iron and steel pipes are not subject to tuberculation, and the later conviction that in this respect they have little or no advantage over cast iron, have also done much to make possible a better estimate of the real merits of this pipe.

The author regrets that as yet so few experimental determinations of the carrying capacity of stave pipe under varying conditions of diameter and grade have been made. In engineering literature he knows of only four in which the proper conditions have been sufficiently observed to render them worthy of mention. They are as follows:

(1) An experiment on a long line of 30-inch pipe (No. 1, Table 5) briefly mentioned by J. D. Schuyler, M. Am. Soc. C. E. In this case, with a mean velocity of about 2.33 feet per second, the derived value of n in the Kutter formula was found to be a little less than 0.010.

(2) An experiment by the author on an 18-inch pipe (No. 8, Table 5), in which the value of c in $v = c\sqrt{rs}$ was found to be 133, with a mean velocity of 3.60 feet per second. This result corresponds to a value for n in the Kutter formula of a little less than 0.010.

(3) Experiments on a section of 6-foot pipe (No. 12, Table 5), described by Charles D. Marx, M. Am. Soc. C. E.; Charles B. Wing, Assoc. M. Am. Soc. C. E. and Leander M. Hoskins. The results gave average values for c as follows:

| Velocity in Feet per Second. | Corresponding Value of c. |
|---|---|
| 1.0 | 97 |
| 2.0 | 115 |
| 3.0 | 122 |
| 4.0 | 126 |

The values of n corresponding to these results vary from 0.012 to 0.015.

(4) Experiments by the author on a line of 14-inch pipe (No. 13, Table 5), in which the values of c averaged as follows:

| Velocity in Feet per Second. | Corresponding Value of c. |
|---|---|
| 0.7 | 102 |
| 1.2 | 111 |
| 1.5 | 112 |

The values for n corresponding to these results vary from 0.0107 to 0.011. The velocities, it will be observed, are all very low.

The results of the Ogden experiments are so much at variance with the great preponderance of credible evidence bearing on this question, that without wishing to seem to discredit them, the author awaits further verification of the results before accepting them as conclusive.

In Table No. 6, showing the values of c in the formula $v = c\sqrt{r\ s}$, for clean pipes of staves, cast iron and lap-riveted steel, the values for the stave and cast iron pipes are deduced by aid of the Kutter formula, assuming a value for n of 0.010 for the stave pipe, of 0.011 for the cast pipe when clean, and 0.014 when tuberculated, a velocity of flow of 3 feet per second being assumed. For steel riveted pipes the uniform value of 111 is given for c for all diameters, and a deduction of 20 per cent. is made in determining the values for tuberculated pipes.

The calculated values are for the most part interpolated from tables, and may be slightly in error in the last figure.

The most that the author claims for the assumptions on which these tables are based is that they are in substantial accordance with the best of our experimental knowledge; and that when such knowledge is wanting one can do no better than to rely upon the Kutter formula. Future investigation will doubtless necessitate many modifications, but will scarcely change the designated order of relative efficiencies.

TABLE NO. 6.—VALUES OF c IN THE FORMULA $v = c\sqrt{r\,s}$ FOR CLEAN PIPES OF WOOD, CAST IRON AND RIVETED STEEL; AND FOR CAST IRON AND STEEL RIVETED PIPES WHEN TUBERCULATED.

| Diameter. | Stave. | Cast iron. | | Steel riveted. | |
|---|---|---|---|---|---|
| | n 0.010. | Clean. n. 0.011. | Rough. n 0.014. | Clean. | Rough. |
| 12 | 119 | 105 | 77 | 111 | 89 |
| 18 | 130 | 117 | 86 | 111 | 89 |
| 24 | 137 | 123 | 92 | 111 | 89 |
| 30 | 143 | 129 | 97 | 111 | 89 |
| 36 | 148 | 133 | 101 | 111 | 89 |
| 42 | 152 | 136 | 105 | 111 | 89 |
| 48 | 154 | 138 | 108 | 111 | 89 |
| 54 | 157 | 140 | 110 | 111 | 89 |
| 60 | 159 | 142 | 112 | 111 | 89 |
| 66 | 161 | 144 | 114 | 111 | 89 |
| 72 | 163 | 146 | 116 | 111 | 89 |

If the discharging capacity of the stave pipe of any diameter is designated as 100, the relative discharging capacities of the others will be as follows:

TABLE NO. 7.—RELATIVE DISCHARGING CAPACITY OF PIPES, STAVE PIPE BEING TAKEN AS 100.

| Diameter. | Stave. | Cast iron. | | Steel riveted. | |
|---|---|---|---|---|---|
| | | Clean. | Rough. | Clean. | Rough. |
| 12 | 100 | 88 | 65 | 93 | 74 |
| 18 | 100 | 90 | 66 | 86 | 69 |
| 24 | 100 | 90 | 67 | 81 | 65 |
| 30 | 100 | 90 | 68 | 78 | 62 |
| 36 | 100 | 90 | 69 | 75 | 60 |
| 42 | 100 | 90 | 69 | 73 | 58 |
| 48 | 100 | 90 | 70 | 72 | 58 |
| 54 | 100 | 89 | 70 | 71 | 57 |
| 60 | 100 | 89 | 70 | 70 | 56 |
| 66 | 100 | 90 | 71 | 69 | 55 |
| 72 | 100 | 90 | 71 | 68 | 54 |

If the premises are correct, and they are believed to be in harmony with present knowledge, these results are of a startling nature. Clean cast iron pipes would seem to have about 90 per cent. of the carrying capacity of stave pipes, while if seriously tuberculated, a condition which usually prevails after a few years of use, they discharge only about two-thirds as much as stave pipes of the same sizes.

The steel pipe discharges, when clean, from 93 per cent., in case of a 12-inch pipe, to 68 per cent. in case of a 6-foot pipe, of the amount which might be expected from stave pipes of the same sizes, while if the steel pipe is tuberculated to an extent that may readily occur in from ten to fifteen years of use, these discharges may fall to 74 per cent. and 54 per cent., respectively.

Omitting other considerations, is not the value of a pipe line investment proportional to its delivering capacity? Do not these percentages then represent approximately the relative values of these different classes of pipes as investments?

## COST.

Variability in market quotations on materials, freight rates, wages, the effect of geographical location of these, the conditions affecting

hauling and the manner of executing the work make it impossible to deduce an accurate comparison of cost which will admit of general application. For present purposes, however, it is not necessary to attempt more than to convey a general idea of the order of the respective costs of the three classes of pipe considered, at the terminal points designated. For this purpose Tables Nos. 8 and 9 have been prepared with considerable care.

It is assumed that the stave pipe is designed in accordance with the formulas previously deduced, an assumption which somewhat increases the cost, particularly for light pressures, above that which would result were the bands spaced in accordance with the formulas more commonly used.

The steel pipe is supposed to be double riveted on the straight seams and single riveted on round seams as ordinarily built, and coated with asphalt. The mill price for sheet steel is taken at from $1.60 for No. 14 plate to $1.25 for thicknesses greater than No. 8.

The cast pipe is supposed to be proportioned as to thickness by the formula of the Warren Foundry, and the prices assumed per ton are $19 at Chicago and $26 at San Francisco, the latter figure being the lowest yet quoted there.

TABLE NO. 8.—COMPARATIVE COST OF PIPE AT CHICAGO.
Including Laying but Omitting Haul.

| | Stave. | | | | Steel riveted. | | | | | | | | Cast iron. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nom. diameters. | 25-ft. head. | 50-ft. head. | 100-ft. head. | 200-ft. head. | No. 14 B. W. G. | No. 12 B. W. G. | No. 10 B. W. G. | No. 8 B. W. G. | No. 6 B. W. G. | ¼ inch. | 5-16 inch. | ⅜ inch. | 25-ft. head. | 50-ft. head. | 100-ft. head. | 200-ft. head. |
| 12 | .42 | .49 | .63 | .85 | .32 | .38 | .44 | | | | | | .73 | .77 | .84 | 1.00 |
| 18 | .69 | .80 | 1.02 | 1.46 | | .57 | .65 | .78 | .98 | | | | 1.29 | 1.35 | 1.46 | 1.70 |
| 24 | .79 | .91 | 1.14 | 1.61 | | | .85 | 1.04 | 1.28 | 1.55 | 1.99 | | 1.91 | 2.00 | 2.18 | 2.55 |
| 30 | .96 | 1.12 | 1.44 | 2.06 | | | | 1.27 | 1.59 | 1.93 | 2.46 | 3.04 | 2.67 | 2.80 | 3.07 | 3.61 |
| 36 | 1.19 | 1.40 | 1.82 | 2.65 | | | | 1.55 | 1.93 | 2.30 | 2.92 | 3.58 | 3.47 | 3.67 | 4.06 | 4.85 |
| 42 | 1.40 | 1.68 | 2.23 | 3.33 | | | | 1.61 | 2.18 | 2.66 | 3.37 | 4.12 | 4.42 | 4.69 | 5.22 | 6.28 |
| 48 | 1.55 | 1.85 | 2.46 | 3.67 | | | | | 2.48 | 3.03 | 3.83 | 4.66 | 5.50 | 5.84 | 6.53 | 7.92 |
| 54 | 2.23 | 2.62 | 3.43 | 5.02 | | | | | 2.80 | 3.41 | 4.29 | 5.21 | 6.65 | 7.10 | 8.00 | 9.78 |
| 60 | 2.85 | 3.35 | 4.37 | 6.40 | | | | | | 3.79 | 4.75 | 5.74 | 8.04 | 8.63 | 9.80 | 12.13 |
| 66 | 3.21 | 3.81 | 5.00 | 7.38 | | | | | | 4.35 | 5.21 | 6.29 | 9 51 | 10.16 | 11.55 | 14.05 |
| 72 | 3.65 | 4.38 | 5.83 | 8.73 | | | | | | 4.52 | 5.66 | 6.83 | 11.32 | 12.00 | 13.26 | 16.00 |

COMPARATIVE COST OF PIPE AT SAN FRANCISCO.

Including Laying but Omitting Haul.

| | Stave. | | | | Steel Riveted. | | | | | | | | Cast Iron. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nom. Diameters. | 25 ft. Head. | 50 ft. Head. | 100 ft. Head. | 200 ft. Head. | No. 14 B. W. G. | No. 12 B. W. G. | No. 10 B. W. G. | No. 8 B. W. G. | No. 6 B. W. G. | ¼ inch. | 5-16 inch. | ⅜ inch. | 25 ft. Head. | 50 ft. Head. | 100 ft. Head. | 200 ft. Head. |
| 12 | .37 | .45 | .61 | .94 | .45 | .52 | .60 | | | | | | .94 | .99 | 1.09 | 1.31 |
| 18 | .58 | .71 | .96 | 1.47 | | .77 | .88 | 1.04 | 1.30 | | | | 1.65 | 1.73 | 1.89 | 2.21 |
| 24 | .76 | .96 | 1.35 | 2.12 | | | 1.01 | 1.35 | 1.67 | 1.97 | 2.51 | | 2 50 | 2 62 | 2.86 | 3.37 |
| 30 | .83 | 1.03 | 1.43 | 2 23 | | | | 1 64 | 2 04 | 2 45 | 3.10 | 3.79 | 3.52 | 3.70 | 4.07 | 4.81 |
| 36 | 1.02 | 1.29 | 1.83 | 2.90 | | | | 1.80 | 2.44 | 2.92 | 3.67 | 4.49 | 4.60 | 4.87 | 5.40 | 6 50 |
| 42 | 1.23 | 1.58 | 2.28 | 3 69 | | | | 2.27 | 2.80 | 3.37 | 4.24 | 5.12 | 5 87 | 6.25 | 6.97 | 8.43 |
| 48 | 1.34 | 1.73 | 2.51 | 4.07 | | | | | 3.14 | 3.80 | 4.78 | 5.78 | 7.33 | 7.80 | 8.73 | 10 64 |
| 54 | 1.94 | 2 45 | 3.49 | 5.52 | | | | | 3.55 | 4.32 | 5 37 | 6 47 | 8.86 | 9.47 | 10 69 | 13.15 |
| 60 | 2.44 | 3.09 | 4.39 | 7.00 | | | | | | 4 87 | 5.95 | 7.24 | 10.73 | 11.54 | 13.14 | 16 33 |
| 66 | 2.79 | 3.57 | 5.14 | 8.26 | | | | | | 5.43 | 6.54 | 7.81 | 12.70 | 13.69 | 15 45 | 18 92 |
| 72 | 3.22 | 4.15 | 6.04 | 9.78 | | | | | | 5.90 | 7.09 | 8.50 | 15.12 | 16.05 | 17.78 | 21.53 |

The figures are supposed to include only the principal common items of expense, with no profit to the contractor. They are therefore, perhaps, in every case somewhat below probable cost, and are intended for use by way of comparison only.

A contrast of actual quotations for particular cases would, in almost every instance, show a greater advantage to the stave pipe than the tables indicate. Especially would this be true where a considerable haul would be necessary, or where the work is far removed from pipe shops and of insufficient magnitude to justify manufacturing the riveted pipe on the ground, or where the site is difficult of access. The tables indeed assume the most favorable conditions for the use of the steel riveted or the cast pipes.

While cost, durability and carrying capacity chiefly characterize the efficiency of a pipe line and determine its value as an economic investment, there are lesser considerations which are of peculiar interest in relation to stave pipe. Two of these — ease of repair and extent of unavoidable leakage — the author wishes to briefly consider before closing this paper.

### EASE OF REPAIR.

The manner of its construction in being built of independent staves held together by removable bands, makes possible the taking out of defective staves and, if need be, the replacing with new materials of entire sections at any point on the line, without other tools than a saw, square, wrench and flat chisel, and with remarkable dispatch. Two striking instances illustrating the facility and speed with which such repairs can be made have come to the author's attention: On the Astoria gravity line, 18 inches in diameter, before backfilling was completed, a large fir tree fell across the trench, broke in two, and one section descended endwise upon the pipe, crushing in and destroying the top staves. The accident was not discovered until the pipe up to this point was filled with water. One man made the repairs and had the water flowing under full head — about 70 feet — in two hours after the tree was removed from the trench. One of the 4-foot syphons on the conduit of the San Gabriel Power Company was crushed to pieces by the falling from the mountain-side of a large boulder. The repairs were made and pipe ready for water within four hours after the removal of the obstructing rock. Such results must strongly appeal to engineers familiar with the maintenance of such structures, and having knowledge of the usual seriousness of delay in accomplishing repairs. In the correcting of small leaks it is seldom necessary to do more than insert a few small wedges.

### EXTENT OF UNAVOIDABLE LEAKAGE

The question of leakage in this class of construction is most interesting; and in the constructing of very long lines designed for low velocities may become of the greatest importance.

There can be little doubt that careless construction will usually result in excessive leakage, as is indeed true of any class of pipe. The important question, rather, is: to what extent is leakage unavoidable with skillful construction? The author has knowledge of results secured in two instances on work built under his supervision: One at Astoria, an observation of an assistant engineer, the other a carefully conducted test on a 14-inch extension of the system of the West Los Angeles Water Company supplying the Pacific Branch of the National Soldiers' Home with water, mentioned on page 38. In the first before-mentioned, the upper 2¼

AN ACCIDENT THAT WAS REPAIRED IN 4 HOURS.

miles of the 18-inch gravity line built of yellow fir stave, was filled with water. The gate at head was not wholly tight but admitted a trickling stream insignificant in amount. The lower end terminated at a gate with a relief overflow two feet above the hydraulic grade line. The small trickling stream entering at the upper end was observed to be passing out of the overflow at the lower end, apparently undiminished in volume. The intervening pipe in accordance with proper practice was all located well below the controlling summits, that it might be under pressure at all stages of flow.

In the second instance, the pipe had been in use for some months at the time of test. The location, as in the first case, was such as to cause the pressure, excepting at occasional short summits, to be little affected by the rate of flow. A section of the line four and one-half miles in length, having a permanent 4-foot weir at each end, was experimented upon. Hook gauges set in the masonry structure at each point were used in measuring heads. In the first experiment, the rate of flow was reduced to a discharge of about one inch in head on the weir, without being able to detect any certain loss. A temporary weir but eight inches in length was then substituted for the 4-foot weir in each case, and the discharge reduced to a head of about an inch, and again no diminution could be observed at the lower weir. The experiments were continued for a number of hours that there might be no doubt as to the minimum constant discharge being secured. The delicacy of this latter test was such that, with due allowance for the usual small unavoidable errors in such experiments, the author felt justified in pronouncing the pipe practically without leakage.

## CONCLUSION.

If, then, stave pipe stands unquestionably first in point of both first cost and carrying capacity when contrasted with the two other classes of pipe usually considered, not to mention less vital constructive advantages, and second only to cast iron in length of life, does it not logically follow that it is destined to a greatly extended use? And is it not clear, that though the great saving in first cost incident to local causes has fostered its rapid introduction in the West, yet the field of its economic usefulness is by no means compassed by such narrow limits? If these querries are answered in the affirmative, is it not deserving the careful consideration of en-

gineers who conscientiously and studiously seek a wise economy in the design and execution of hydraulic works?

DISCUSSION.

By CHAS. K. WALKER, Superintendent.

As a desire has been expressed for a description of the stave pipe built by J. F. Fanning, C. E., at Manchester, N. H., the following is submitted:

No examination has been made of the pipe since it was built, in 1872, but from reports and descriptions by Col. Fanning it appears that the pipe extends from the canal to the turbine wheels in the pumping station, a distance of 600 feet. It was made of hard pine staves, 4 inches thick, laid so as to break joints, and hooped with $2\frac{1}{2}'' \times \frac{5}{8}''$ wrought iron hoops spaced eighteen inches apart. The hoops were made in two pieces, which were bolted together with $1\frac{1}{8}''$ bolts. The butt ends of the staves were made tight by a sheet of steel inserted in saw cuts in each end. This steel projected slightly beyond the edge of the stave and penetrated the adjoining stave. At two slight changes in grade in the pipe butt joints are made which are covered with wrought iron hoops. The pipe is under 12 to 40 feet head, and is covered with about 6 feet of earth.

The pipe has never leaked, and has never been uncovered except at one place for the insertion of a stop cock, where it was apparently sound.

By W. H. RICHARDS.

It may be of interest to say that a 24-inch submerged sewer 900 feet in length was built under the direction of the writer in New London, Conn., in 1892, of cypress staves secured by $\frac{3}{4}''$ galvanized round steel hoops. The butt joints being secured in this instance by wooden trenails or "stop waters" driven into a hole bored through the joint on a line tangent to the radius. This proved to be a very easy and effective way to secure the butt joints. This sewer being laid under the bottom of the harbor in salt water and mud, the wooden pipe was selected not only because it could be more easily laid, but because it was considered to be more durable than any metal pipe would have been under the conditions which obtained.

# IMPROVED WYCKOFF WATER-PIPE.

BY GEORGE L. WELLS, CIVIL ENGINEER, BAY CITY, MICH.

[*Read January 11, 1899.*]

Improved Wyckoff water pipe is made of wooden shells bored and turned, from solid logs and banded spirally with iron, steel or bronze bands to provide the strength. The outside is thoroughly coated with pitch by rolling the finished pipe on steam heated rollers which work in a bath of melted pitch maintained at about 350 degrees F. After being coated the pipe is rolled on a bed of sawdust or planer shavings and then smoothed on cold rolls. There are two manners of making joints. For low pressure pipe a mortise four inches long is bored in one end of a length and a tenon to make a tight fit is turned on the other end. For high pressure pipe, such as is used in municipal water works systems, a mortise is bored in both ends of the shell and a wood thimble, usually made from white pine thoroughly seasoned, with the same inside diameter as the pipe and with an outside diameter one-eighth of an inch larger than the diameter of the mortise into which it fits. After forming the joints and just before coating the outside, each piece of pipe is tested under pump pressure from forty to two hundred pounds per square inch according to the weight of banding and the service for which the pipe is designed.

Such in brief is a description of the pipe and its manufacture, details of which will be more fully discussed.

## ORIGIN OF NAME.

In 1860 a patent was granted to Mr. A. Wyckoff of Elmira, N. Y., for an augur which bored a log taking out a core, so that a number of concentric pipe shells could be bored from one log. The name "Improved Wyckoff Water Pipe" has been adopted by the other manufacturers who have made improvements both in the methods of manufacturing and in the pipe itself.

## DURABILITY.

In selecting a pipe for a system of water works the question of durability is one of prime importance, and the selection or rejection of any form of pipe is usually decided according to the purchasers' opinion of the durability.

Investigation into the durability of improved Wyckoff water pipe has been made almost entirely as to the life of the wood in the shells. When that question is settled very little doubt exists as to the other merits claimed for the pipe.

It is a well known fact among people who work with timber that when the sap is taken out of it—the fibre freed from albumen, starch, sugar, etc., contained in the sap, which ferment and promote the life of germs which cause the decay—that the fibre is practically imperishable. Every process for the preservation of timber depends entirely upon the extraction of the sap. Anticeptics used to preserve the wood simply kill or ward off the attacks of extraneous germs which would feed upon it.

When Wyckoff water pipe is placed in a water works system, water is forced into all the pores of the wooden shells. The supply is constant and the water in the pores is continually though gradually renewed. By this means all the sap in the shell is dissolved and washed out leaving the wood "seasoned." The writer is aware that the popular understanding of the word "seasoned" when applied to wood, implied that the sap has been taken out by exposure to the wind, heated air, or extracted in a vacuum, all of which leaves the timber dry, but he believes that experienced engineers generally use the term to denote timber which has been freed from sap whether wet or dry, and it is used in that sense here. Logs which have been floated from the forests to the mills, and which have laid in water long enough to have it displace the sap, are found to make lumber which seasons more quickly and thoroughly than lumber made from logs hauled to the mills by teams or railroad.

That the water fills the pores of the wooden shells of Wyckoff pipe more thoroughly than the sap did while they were in the trees is evidenced by the fact that the shells become much harder and firmer after they have been used in water mains.

In other branches of engineering, timber is made use of extensively where durability is all important. Its extensive use as piling and for crib work in foundations for bridges, large and costly permanent buildings and in river and harbor improvements is too well known to need discussion here. It is simply referred to here to call to mind the great use made of timber where the conditions are very similar to those under which timber is used in Wyckoff pipe. In a water works system where the pressure is 43.4 pounds per square inch the pores are as thoroughly filled as if submerged in 100 feet of water, etc.

It is recognized that in order for timber to decay there must be three conditions existing at the same time, viz: a temperature from 50 degrees to 150 degrees F., in the presence of air and with the timber in a moderate condition of moisture. The absence of any one of these conditions makes decay impossible. When used in the shell of a water pipe, the only one of these conditions affecting the wood is that of temperature.

Besides the foregoing reasons for believing that wood used in the shell of a water pipe is a durable material, we have the experience of the pipe to prove it. The system of water works at Bay City, Michigan, was constructed in 1872. Additions have been made until there are now about 35 miles of Wyckoff pipe made use of in the system. During the past summer while some street improvements were being made, the writer had the opportunity to examine some of the first pipe laid and it was found to be in a perfect state of preservation. A large number of towns in the middle and western states have had a similar experience. Unfortunately the early makers of the Wyckoff pipe had not perfected means for banding the pipe securely, and there were some failures of the pipe for the lack of strength on this account. In 1870 Mr. M. F. Wilcox of Bay City, Michigan, designed and patented a machine with an automatic brake which applied the band under a tension so that all trouble of that kind was eliminated.

In the eastern cities of the United States, about 100 years ago, there were quite a large number of water works systems constructed using bored logs for mains. The logs were not turned and many times the bark was not taken off. The logs were not banded. The great thickness of wood left about the bored hole

was depended upon for strength. Various sorts of devices were used for joining lengths of these crude pipes together. As population increased and there was demand for greater pressures than these old log pipes would stand, they went out of use. But these old log systems bear evidence that wood is well adapted for use in the manufacture of water conductors. Within the last three and a half years the writer has seen the old bored logs used in the Jamaica Pond system in Boston, in the old Manhattan system in New York and in the old system in Philadelphia. These old bored logs had been recently taken out of the streets and although they had not been in use for a number of years, they were in a remarkably good state of preservation. The pipe of the old Jamaica Pond water works system was taken out of Harrison Street in Boston, where excavations were being made for conduits for electric light wires in the summer of 1895. One of the workmen had cut the pipe with an ax and the interior timber was as bright and fresh looking as that of a newly cut log. Trautwine's Engineer's Pocket Book, Edition of 1882, page 577, says that pipes which had been laid 50 or 60 years were relaid in factories, etc. At Fayetteville, N. C., a system of water works was constructed between 1820 and 1823 using three-inch bored logs under a head of about forty feet. In December, 1893, the Superintendent of the Fayetteville works sent a sectional block which he had cut out of one of these logs a few days before. In the letter accompanying the block he stated that the block had been in pipe which had been in continual use for at least seventy years. The block was in a perfect state of preservation. The block is still in the writer's possession and is bright and sound and does not show any sign of decay.

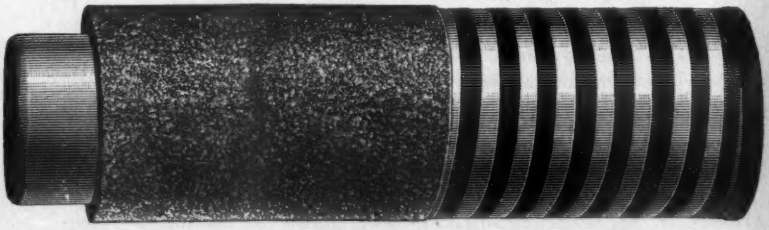
Other points of the general durability of improved Wyckoff water pipe will be discussed or referred to later.

## STRENGTH.

The standard width of bands is one inch. Various thicknesses of bands are used which are spaced from one-half inch to four inches between the spiral wrappings according to the strength required.

For extremely light pressures of ten pounds or less the ends only are banded.

The cut of the pipe shows one end coated and the bare band and shell at the other end. A thimble for connecting lengths together is shown on the left end of the cut. The cut, however, is defective in one respect, as it does not show the band run doubly over the entire length of the mortise.



The spiral bands are applied to the wood shells in a machine with an automatic brake referred to above, and are fastened only at the ends. The band is started a few inches back of the mortise by driving the end into the shell. It is then wrapped over the entire circumference at that point, then run spirally to within half an inch of the nearer end, then back over the whole length of the pipe to within half an inch of the other end, then run back over the mortise and fastened to the shell with screws designed for that purpose. These fastenings, though simple, have been found to be secure and reliable.

Bands are now, and have for some years, been made of Bessemer steel having a tensile strength of 70,000 pounds per square inch. Tobin bronze bands have been used on some pipe where mineral waters containing large quantities of compounds of sulphur were to be conveyed from mineral springs to points where they were to be used. With the wooden shell and bronze band there is nothing about such pipe for which sulphur has an affinity, and it has worked very successfully.

The steel bands and wood of the shell both being elastic enables the pipe to withstand the shock due to the water rams and pounding of pumps. Some years ago, to see just how this would work in practice, the writer made an experiment. A length of 160-pound test-pipe 6 inches in diameter was put into a hydraulic test-

ing apparatus, and the pressure run up to 350 pounds per square inch when the wood shell split nearly midway between the ends. The split was about a foot long and less than an eighth of an inch wide at the centre. The pressure was held at 350 pounds for a few minutes. The size of the split did not increase. It seemed to act as a safety valve, so to speak. As the pressure was gradually reduced the split became narrower. At 120 pounds it was closed, but small drops escaped—possibly a pint a minute. At 100 pounds water could just be seen oozing from the split, and at 80 pounds it was so tight that there was no water escaping from it.

This feature of the improved Wyckoff water pipe is one that makes it well adapted for the mains in a gravity or direct pressure system of water works where the head or pumps supply a fire pressure, as the shock from the interrupted flow or pounding of the pumps will be largely dissipated in the elastic walls of the pipe, and in case of a shock great enough to cause a rupture, the wood will split and permit water to escape until the normal pressure is again reached, when the split will close without any inconvenience being experienced, and without interfering with the work of the fire department. The writer does not know of any of this pipe breaking which caused any flood or washouts in the streets. The break in the wood when it occurs relieves the bands from excessive pressure, and they are able to stand the strain put upon them.

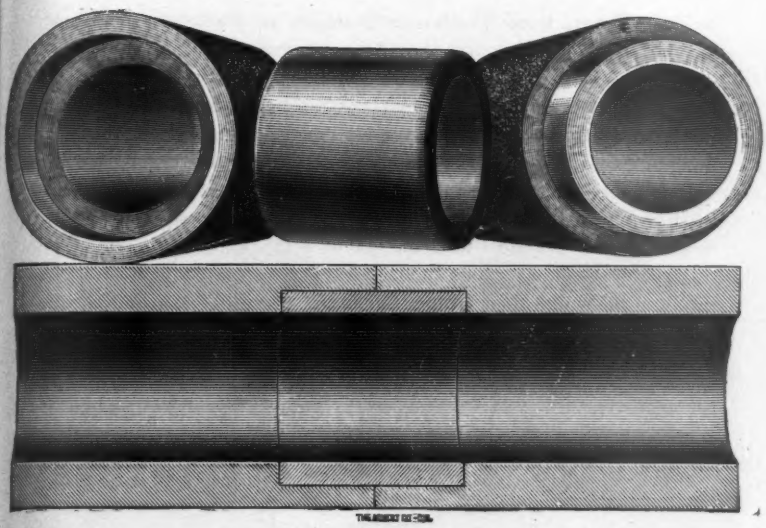
The pipe is designed for the entire strain due to the pressure to be carried by the spiral banding, the wood acting as a beam in carrying the pressure over the spaces between the banding. The principal duty required of the shell is to stand as a neutral material against the chemical action of the water or anything which it holds in solution, and as a heat insulator to protect water from freezing. In practice it amounts to an iron, steel or bronze pipe (according to material used in banding), with a lining of wood. As the wood is a non-conductor of heat it is able to resist the action of frost on the water to a marked degree, and in case of an exposure to a temperature sufficient to freeze water in the pipe the elasticity of the pipe is enough to save it from permanent or serious damage. In December, 1892, at Norway, in the Upper Peninsula of Michigan, the writer was finishing the construction of a new waterworks system in which all of the mains were improved Wyckoff pipe. On a line of six-inch pipe about half a mile long, the

earth excavated from the trench became frozen by a sudden dropping of temperature so that it had to be picked before it could be back filled. The chunks of frozen earth could not permit much settlement over the pipe, and cold air had very little difficulty in reaching the pipe. The city officials were anxious to have water let into the entire system for fire protection as soon as construction was finished. Water was let in. Cold weather, at very low temperature even for that cold climate, continued for several weeks, with the result that no water was obtained from that half mile of pipe until the following May on account of the water in the main having been frozen. Soon after it thawed a pressure of 170 pounds per square inch was placed upon the line without developing any leaks, and the line has given good service since.

## JOINTS.

As stated at the beginning of this paper, there are two ways of making the joints. The ordinary mortise and tenon joints for low pressure pipe will hardly need any comments here, but the thimble joints for high pressure pipe are a matter of interest. The thimbles in pipe 5 inches in diameter and larger are eight inches long and approximately half as thick as the wood shell of the pipe. They are made of dry seasoned white pine with an inside diameter the same as that of the pipe, and an outside diameter one-eighth of an inch larger than the diameter of the mortise in the end of the pipe. When these thimbles are driven into the mortises, they are, of course, a very tight fit to begin with, but when water is let in and the pipe and thimbles become water soaked, the joints become so tight as to hold the water with high pressure in gravity and direct pumping water works systems. The mortises in each end of the pipe are half the length of the thimbles, and half of the thickness of the shell is bored away in forming it. When the pipe is laid it has the same inside and outside diameters continuously.

The thimbles are driven into one end of the pipe before leaving the factory. Before driving the thimble into the pipe, both mortises are painted with residium oil, and the protruding portion of the thimble is also painted on the outside with it to lubricate the surfaces to facilitate the work of driving them together. The joint is well illustrated in the cut. Thimbles are slightly rounded off at the ends to allow a slight entrance into the mortise before driving.



LAYING.

After the trench has been prepared the pipe is lowered by hand. Two men are kept in the trench all the time, one of whom takes hold of and lowers the end of the pipe containing the thimble. He then carefully brushes off the thimble with a small hand broom, and sweeps out the mortise which the thimble is about to enter to make sure that nothing will be present to scratch or mar the joint. After lowering and entering several lengths of pipe—if laying the smaller sizes—he places a driving block in the mortise of the last pipe lowered to receive the blows of the ram which drive the lengths of pipe together. The other man lowers the end of the pipe with the open mortise, and helps to handle it while the thimble is being entered, and operates on the ram.

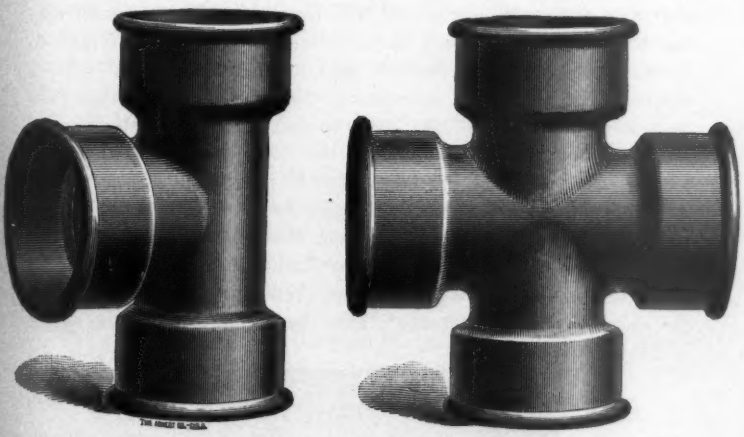
The driving block is made of oak or some hard wood, turned so that one end of it sets squarely against the shoulder of the shell at the inner end of the mortise. The other end of the driving block is rounding, and is struck by the ram. Iron bands are driven on the driving block to keep it from splitting. A handle of 1½-inch gas pipe, 2½ to 3 feet long, enters a hole bored in the centre of the block at an angle of 45 degrees. The ram should be made of

a block of hard wood 8 inches or 10 inches in diameter, and about 4½ feet long. Both ends should be banded with iron rings. A handle three feet long making an angle of 20 degrees is fastened to one end, and a staple and bull ring put in the middle. The ram is suspended by a rope tied to the bull ring, and passing around a long pole or 4″x4″ stick thrown across the top of the trench, and its adjustments are governed and the rope held in position by a workman. Five or six blows of the ram are usually enough to drive up a joint. It is practical to drive six or eight lengths of pipe 6″ in diameter or smaller at one time, and two or three lengths of eight and ten-inch pipe at one time, but it is better to drive one length of the larger pipe at a time. By driving several lengths together at once considerable time and expense can be saved. The only difficulty encountered is when the sides of the trench have a tendency to cave. By having the blows for a number of lengths struck at one place, earth from the sides of the bank is likely to be jarred down. But if only one length is driven at a time this trouble can be avoided. A considerable quantity of Wyckoff pipe has been laid by using a heavy sledge to strike against the driving block and good work accomplished, but a heavier blow can be struck with a ram with less exertion from a workman, and will not tire him out like handling a heavy sledge. Besides, this pipe can be laid much faster and cheaper by using the ram.

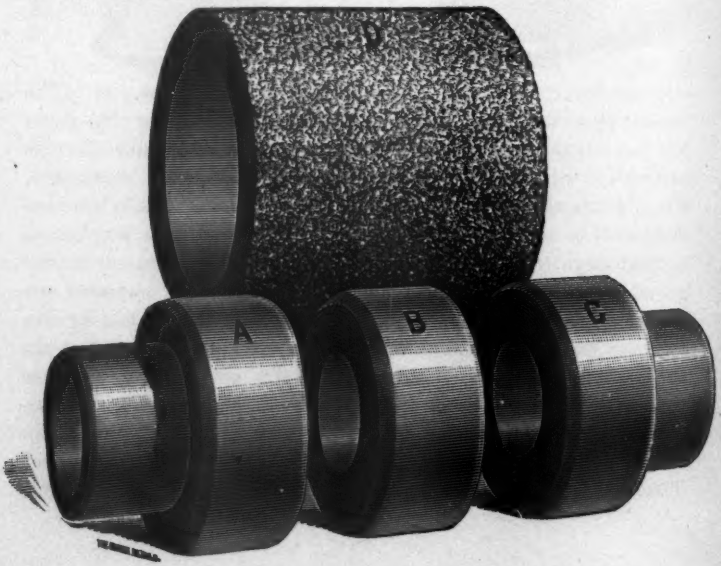
In driving the pipe together the ends should be brought up tight, but in making slight deflections in alignment or grade, a small gap or opening on one side of a joint can be left without detriment to the work.

As there is no lead or packing used in making a joint, it is not necessary to have a dry trench to work in. The only limit to the quantity of water in a trench is that there should not be enough to float the pipe. If there is danger of enough water getting into the trench to float the pipe, then the trench should be back filled enough to hold it down or anchor it. Wyckoff pipe can be laid through marshes, swamps and wet ground with nearly as much facility as through dry ground. Of course, no bell holes are required. Care should be taken to see that hot pitch is placed on parts where the coating may have been chafed off in transportation or handling. This is not extensive in any event, but it is a point which needs watching. Four men will constitute a pipe laying

gang for pipe 6 inches or smaller, and five or six men for larger sizes. Common laborers of ordinary intelligence will make good pipe layers with half a day's experience to guide them. In laying pipe in a large system it is a good plan to have a competent foreman to handle the pipe crew, but in a small system one foreman can easily handle the whole work. In low pressure pipe systems, the tees and crosses are made of wood, but for the high pressure systems short cast iron tees and crosses are used. The bells of these specials are bored the same diameter as the mortises in the pipe. The entrances of these mortises are slightly rounded so that the metal will not cut the thimbles in driving. Any standard make of valve or hydrant can be used by boring the bells in a similar manner. Plugs are turned to fit mortises of pipe which are used to close up dead ends or unused branches of specials. Dead ends are braced against large stone, timber or plank, according to the nature of the ground and convenience of materials. Tees and hydrants are braced in the same way. In connecting two parts of a pipe line together, several methods are practiced. One method is to lay the two parts of the line to a point within fifty or seventy-five feet of each other, then the exact distance to be filled with pipe is measured. After selecting the pipe to fill the space, lay all pipe in the usual manner, leaving the last mortise and thimble uncoupled. Then the two ends of the pipe line are raised four or five feet until



the thimble will enter the mortise, when it is gradually lowered and the weight of the pipe in lowering forces the thimble into the mortise, so that when completed it has the same appearance as pipe that has been driven together. Another method is to bring three lines together to a cross or tee. The side of the trench for forty feet each side of the special is dug back gradually until the thimble will enter the bell of the special. The pipe and special are worked back into line, bringing the end of the joints close together, and at the same time connecting with the line which is to branch from the tee. Another method is to bring the two ends of pipe to be connected within a foot of each other and connect with a sleeve. The sleeve has an internal diameter slightly larger than the outside diameter of the pipe, so that it can be easily slipped over the pipe. The small end of the reducers fit into the mortises of the pipe, and the large ends fit the inside of the sleeve. A filling piece, termed a "Dutchman," is four inches long, having the same inside diameter as the pipe it connects, and the outside diameter the same as the internal diameter of the sleeve. The sleeve itself is a straight piece of pipe shell without mortises. When the reducers and "Dutchman" have been put in place the sleeve is driven over them.



In the cut A and C are reducers, B the "Dutchman," and D the sleeve. The lengths of the large part of reducers are four inches, making the space between pipe just twelve inches, but an adjustment for other measurements can be made by sawing the "Dutchman" for shorter spaces or putting in a piece from another "Dutchman" for a space longer than twelve inches. All of these connections are very simple and can be made quickly and, "like swallowing, more easily done than told." For inserting tees, crosses or valves in established lines of pipes, the length of pipe to be replaced is taken out by sawing through the thimbles at each end of the pipe, and putting in a new length of pipe, sleeve and special to just fill the space of the pipe removed.

In reducing from any diameter of main to a smaller one, reducers made like those shown in the cut are used. It is not good practice to reduce more than two inches at a time. In an ordinary water works system with fair material such as sand, clay or loam to trench through, a gang of forty laborers and one team of horses will trench, lay 1,000 to 1,200 feet of pipe, specials and hydrants, and refill the trenches in a day.

SIZES.

The standard length of the pipe is eight feet and internal diameters run from two inches to 17 inches. The following table gives standard outside diameters of finished pipe.

| Bore. | Outside Diam. | Bore. | Outside Diam. | Bore. | Outside Diam. |
|---|---|---|---|---|---|
| 2 | 4½ | 5 Inch. | 9 Inch. | 12 Inch. | 17 Inch. |
| 3 | 6¼ | 6 " | 10¼ " | 14 " | 19½ " |
| 4 | 7¼ | 8 " | 12½ " | 16 " | 21½ " |
| | | 10 " | 14½ " | 17 " | 22½ " |

Many lengths shorter than eight feet are made, which by leaving slight gaps or openings on the side of the joint in laying enables one to lay a pipe line over very rough ground and will save considerable expense in making cuts to get an even grade. For making deflections or curves in a pipe line "curved" pipe is made, which is the same as the straight Wyckoff pipe, except that the ends are mitred and the mortises bored at right angles to the mitred end. A curve of any desired radius can be laid by the use of this "curved" pipe, and by using it with the straight, a line can be laid over exceedingly rough ground, saving a great deal of expense for grading, which would otherwise have to be done.

### TAPS FOR SERVICE PIPES.

In tapping Wyckoff mains for service pipe, a hole is bored into the shell of the pipe between the banding with an extension bit, to a point within about a quarter of an inch of the inside of the shell. A brass corporation cock with a long coarse thread is then screwed into the shell. The valve in the corporation cock is opened and the hole in the shell completed with a smaller bit. As the bit is withdrawn the augur chips are forced out with the pressure. A workman will soon become so expert in making these connections that he will not lose a quart of water from the main in the whole operation, and do all the work without shutting off the main, and without the use of any tools other than a brace and bit and an ordinary pipe wrench.

### PROTECTION OF BANDING.

The heavy coating of pitch put on the outside of the pipe, protects the outside of the banding from being corroded by anything in the soil. The close contact of the band with the wood shell protects the underside. The coating averages one-eigth of an inch in thickness.

### FRICTION AND WEAR.

When the diameters of the Wyckoff water pipe are well proportioned for the service it is to be placed under there is nothing remarkable about either the friction or the wear of it. The inside surface of the pipe is not quite as smooth as a planed surface of a board, but it is very much smoother than a sawed surface. After the pipe has been used a few years, any small particles that occasionally are left clinging to the surface are washed away and the surface becomes smoother.

In the summer of 1896 the writer made a careful measurement of the velocity of flow of water through a new four-inch Wyckoff pipe line, and found it corresponded with results obtained by Poncelet's Modification of Eytelwein's formula:

$$V = 48\sqrt{\frac{DH}{L+54D}}$$

There is no doubt but what better results are obtained after the pipe is used a few years. The writer considers it safe practice

to use .011 for the coefficient of roughness for n for new Wyckoff pipe and .01 to .0105 for n for Wyckoff pipe after several years' use when making calculations by Kutter's formula. Numerous opportunities for observing the wear of Wyckoff pipe have been afforded the writer, but only in one case had any apparent wear taken place. That was in a six-inch pipe which had been in use between ten and eleven years, and the diameter had been increased about one-quarter of an inch. But this line had been very much overworked, and a twenty-inch pipe was substituted for it. This six-inch Wyckoff pipe which was taken up was relaid in other parts of the town, and has given good service since. No incrustations nor barnacles, nor anything of that kind has been observed clinging to the interior of the pipe.

## ELECTROLYSIS.

The writer has been in a position to hear of any injury to improved Wyckoff pipe by the action of electrolysis, and has yet to hear of the first case of damage to it from that source. A great deal of pipe has been laid in the vicinity of electric railroads with very poor bonding, and in some places where rail bonds have been entirely severed. The heavy coating of pitch is a good insulator for the metallic banding. There is a space of one inch between the bands at the end of the pipe, so that there is a break in the metallic circuit on each section of pipe. Electricians give it as their opinion that a current will find a better conductor in the earth than in the wood shell and follow the earth rather than the pipe.

At West Bay City, Michigan, about three years ago, electrolysis destroyed a four-inch line of cast-iron pipe and a lot of lead service pipes. A line of improved Wyckoff main was put in to replace the cast iron pipe, and a lot of two-inch Wyckoff pipe was laid for service pipe, and has not been affected.

It has been recommended that cities bothered by electrolysis put in sections of improved Wyckoff pipe to break the metallic connection furnished to electric currents by cast iron pipe.

## GENERAL REMARKS.

It is a common practice where street grades are lowered to disconnect service pipes at the corporation cocks and fasten the hydrants to connecting tees with two $\frac{3}{4}''$ or $\frac{7}{8}''$ rods and lower the

whole length of improved Wyckoff pipe while the ordinary pressure of the system remains on the pipe, and without causing joints to leak. In lowering the pipe a trench is dug down by the side of the pipe to the depth it is desired to place it. The pipe is braced occasionally to keep it from slipping sideways in uncertain ground, but in firm ground such precaution is unnecessary. After finishing the trench at the side of the pipe the ground is dug out from the under side of it, leaving supports of earth to hold it every 8 or 10 feet. Any kind of blocking may be placed between these supports that will permit the removal of one or two inches of thicknesses at a time. Small pieces of boards and plank and old brick make excellent blocking. The earth and block supports are alternately worked down an inch or two at a time until the pipe lays in the bottom of the trench.

In laying pipe for a gravity line through wild country the pipe need only be buried deep enough to protect it from fire, falling timber, etc.

Connections of improved Wyckoff pipe can be made with cast iron pipe systems by having the bell of the valve bored on one end to fit the thimble of the Wyckoff pipe and a regular cast iron pipe connection on the other end of the valve. In a like manner connections can be made at tees, crosses or with a straightway casting having one bell bored for the Wyckoff pipe and the other for cast iron pipe. A considerable quantity of Wyckoff pipe is used outside of water works systems. Coal miners make extensive use of it for handling sulphur water that is so common in coal mines. It is used about other mines for handling mineral waters that eat out iron pipes for both suction and discharge pipe.

Last spring a line of it was put in Chicago to carry hot soup from one of the packing houses to a glue factory. Another line about two miles long having five-inch internal diameter and a four-inch shell is used by a Canadian distillery to carry hot slops from the distillery to cattle feeding sheds. This line has been in use about eighteen years. A line about eleven miles long was used 15 years to carry brine in Eastern Michigan. It is used in bleacheries, sulphite fibre works and other works where water containing chemicals are to be handled. The various state and United States fisheries also make large use of it.

## EXTENT OF USE.

The writer has not access to records at the time of writing this paper, but would give as an off hand estimate of the amount of improved Wyckoff pipe in use as 1,500 miles. The total mileage of the pipe having wooden shells such as stave pipe, etc., will greatly exceed this mileage. The writer knows of but three systems in New England, those being at Antrim, Belmont and Penacook, all in the state of New Hampshire. There are a number of these works in Pennsylvania, New York, the Middle and Western States and Territories. Michigan probably has a greater mileage than any other one state. Some of the largest systems being Bay City, Michigan, containing about 35 miles of improved Wyckoff pipe, North Tonawanda, N. Y., 31 miles, with Tonawanda, N. Y., an adjoining municipality, with 14 miles more, Ishpenning, Michigan, 26 miles, Ionia, Michigan, 18 miles, DuBois, Pa., 16 miles. In Denver, Colorado, there is a considerable quantity of the pipe used and the entire system at Cripple Creek, Colo., is of improved Wyckoff pipe, but the writer does not remember the exact mileage in use in these places. There are a large number of municipal water works systems using from three to twelve miles of this pipe. It is a notable fact that the iron mining towns of Ishpenning, Negaunee and Norway, Michigan, make large use of improved Wyckoff pipe in their systems.

## COST.

The price of the pipe has varied as other materials varied. At the present time the installation of a distributing system of improved Wyckoff mains will run as much as 25 per cent less than the cost of a system using cast iron mains, and at other points they will cost as much as a system of cast iron pipe, the difference in price depending very largely on freight rates.

# SALT WATER FIRE SYSTEM OF BOSTON.

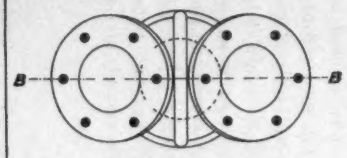
BY FRANK A. MC INNES.

[*Read January 11, 1899.*]

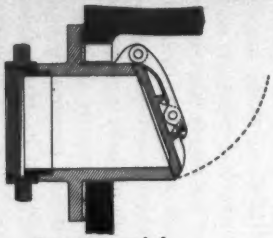
Two fire boats, each of a nominal capacity of 6,000 gallons per minute, constitute the "heavy artillery" of the Boston Fire Department. To extend the radius of action of these boats, making their power available for extinguishing fires at points in the city at a distance from the immediate water front, is the mission of the salt water fire system recently established. Its description is as follows:

A 12-inch cast iron pipe extends from deep water at Central Wharf, through Central, Exchange and Devonshire Streets, Post Office Square and Congress Street, to deep water at Congress Street bridge, a distance of about 5,000 feet. At Central Wharf the line divides into two 10-inch pipes, each of which terminates at a special casting or "boat connection" fitted with six 3½-inch outlets, to which hose can be directly attached. Each outlet has a valve opening inward. One or both boats can connect with the pipe, using all the 12 outlets provided, or as many of them as are desired. The lengths of 3½-inch hose used between boat and "connection" vary from 15 to 30 feet. A similar boat connection is designed for the end of the pipe at Congress Street bridge, but other construction at that point has delayed its completion.

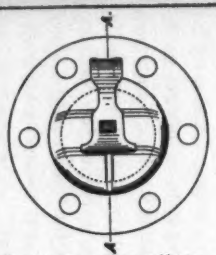
Hydrants are established along the line about 300 feet apart, each gated off from the main pipe; valves set on the main line make it possible to shut off different sections if the need arises, and branches at different points provide for future extension. The system is designed to operate with a maximum pressure, at the Fire Boat, of 200 pounds. Near each end of the line 6-inch relief valves are placed, designed to open in case of undue pressure. Manholes or boxes surrounding valves and hydrants are of masonry. Electrical connection is provided from each hydrant to




END ELEVATION OF Y BRANCH.

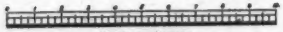


SECTION, LINE A.A.

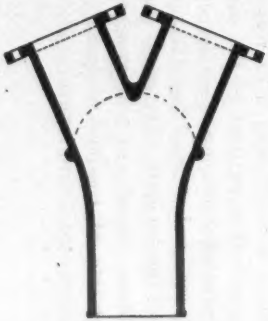


ELEVATION OF CHECK VALVE.

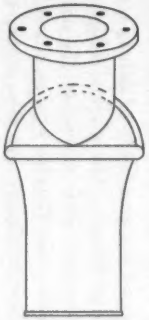
SECTION OF FIRE PIPE.



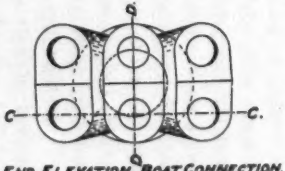
SCALE OF INCHES. FOR CHECK VALVE AND FIRE PIPE.



SECTION, LINE B.B.



SIDE ELEVATION.




END ELEVATION, BOAT CONNECTION.

SECTION, LINE C.C.

SECTION, LINE D.D.

SCALE OF INCHES. FOR FIRE BOAT CONNECTION DETAILS.

fire boat. The main pipe is kept full of water from a 12-inch check valve at Central Wharf to a similar valve at Congress Street bridge, pressure being maintained up to check valves and to foot valves of hydrants and the absence of air assured by means of a one-inch pipe leading from main pipe to a tank in the Post Office building, the tank being supplied directly from the city mains. Two check valves set in this "connection" guard against "too much salt," by closing when fire pressure exceeds the ordinary city pressure. At each end of the line a short length of pipe beyond the limit of solid ground is necessarily exposed and must be maintained empty in cold weather. The system is always ready for use and no time need be lost in preliminary action; in actual operation the fire boat begins to pump slowly just as soon as its first hose connection is made with the pipe, expelling the air from the empty end through an air cock provided for the purpose; when the necessary number of hose connections are made the air is entirely driven out and the boat can "play away." A second boat can connect at any later time and get to work at once.

In Cleveland, Milwaukee, Detroit and Buffalo, systems largely similar have been in successful operation for several years; in each case, at least during cold weather, the pipes are empty when not in actual service; this method permits shallow excavation by eliminating the factor of frost and probably prolongs, to some extent, the life of the pipe. The disadvantages are loss of time in filling the line and the possibility of damage from imprisoned air in the operation of filling. The method adopted in Boston of keeping the pipe always full, while it seemed the part of wisdom on its own merits, was the only feasible one, at a cost at all reasonable. The topography of the streets and the obstructions under their surface made uniform gradients practically impossible. An alignment free from sharp bends, either vertical or horizontal, was insisted upon and obtained with difficulty. At many points the way was absolutely blocked within six feet of the surface by water pipes, gas pipes, sewer connections, fire reservoirs, conduits of all kinds and shapes, etc., etc., and at times the excavation was in brick and concrete rather than in earth. The result was a trench more than seven feet in depth. Great care was exercised in making the lead joints and all points of possible weakness, such as hydrant pots, caps, branches, etc., were treated in a conservative manner and securely

fastened directly from the main pipe by means of tie-rods and collars. Care in these small details had its reward; when the line was tested, under fire pressure, everything held securely and there is no leakage, at least, not enough to be indicated by a one-inch meter on the pipe leading to tank in Post Office. The work was done by men from the Boston Water Department.

It was necessary to meet one condition, concerning which little exact data or in fact data of any kind was on record, viz., the use of salt water in the pipes. Boston is the pioneer in this field as far as fire systems are concerned. The problem was complicated when it was decided to maintain the line always full of water. One fact seemed well established, viz., that iron, composition and salt water would prove a disastrous combination if situated as they would necessarily be were the ordinary valve or hydrant adopted; a galvanic action would undoubtedly result at the expense of the iron; the valves were therefore made of solid composition, fitted with flanged ends, and were insulated from the adjoining pipes by heavy washers or rings of pure rubber; the hydrants are empty when not in use, and the only precautions taken were to separate the composition valve seat from the iron hydrant pot by a lead joint, and to protect the end of the main valve stem (of Norway iron) by a composition cap, making a water tight joint with the bottom of the rubber foot valve.

The use of cast iron in the pipe line was, in a sense, the choice of evils, as either of the other available metals, steel or wrought iron, are much more quickly affected by salt water. A number of cases in the neighborhood of Boston where salt water was pumped through cast iron pipes were investigated, the history of water pipes subjected to salt water on the outside for many years was studied, and all available data considered. The conclusion arrived at was that while cast iron pipe, used for conveying salt water, would suffer more from corrosion than if fresh water were flowing in it, yet it could be depended upon for a number of years. No case was found where a pipe had failed where the question involved only cast iron and salt water, and some were investigated where these conditions had existed for more than twenty years. Under the conditions, with the salt water quiet when the system is not in use, and with pipe of unusually heavy section, it seems very possible that conditions other than the salt water flowing through the

pipe might limit its life. That deadly foe to water pipes, electrolysis, is a worthy rival in the race, and particular conditions of surrounding soil may prove disastrous. If examination shows that the pipe is being quickly affected by the salt water, it will be possible to fill the system with fresh water after service, and to so maintain it until it is next used.

The pipe section used is of the general B. W. W. pattern. An innovation was made in the introduction of two grooves or lead scores in the bell; they were designed as an aid towards ensuring tight joints in caulking, and also add to the strength of the joint; thirty-five to forty pounds of lead were used in each joint. The pipe is unusually heavy, being one inch thick; about one-tenth of an inch was added to the thickness calculated from the ordinary factors in deference to the severe conditions expected; it weighs 142 pounds per foot, or 1704 pounds per length laying twelve feet. Each pipe was subjected to a water pressure at the foundry of 500 pounds per square inch. The coating was made by the well-known method of immersion in a bath of distilled coal tar, particular care being taken to see that the operation was thoroughly performed.

The Bachelder hydrant (so called from the name of the inventor and patentee, Mr. Bachelder, master mechanic of the Boston Water Department), somewhat modified to meet the particular conditions, was adopted. It is a post hydrant, unusually heavy throughout, with three 3-inch outlets, each controlled by an independent valve. The waste is positive, and is operated by a long-handled wrench from the street surface. Through the side of the hydrant a one-inch hole is cored out to carry the electric cable, terminating at the top in a recess which forms a signal box. In this way means of electrical communication was afforded in the hydrant itself, and the need of an independent pillar and signal box was avoided.

The electrical signal service was installed by the Fire Department.

A three-inch, cement-lined wrought iron duct, protected on the outside by concrete, and laid in the main pipe trench, carries a five conductor cable.

A junction, made with a cable belonging to the regular fire alarm service, establishes communication with headquarters, and makes this circuit a part of the fire alarm system of the city.

It is afforded all the appliances, and is subject to the same

# SALT WATER F

## At Post Office Squa

| Experiment Began. | Experiment Ended. | Elapsed Time. | LINE NO. 1. | | | | | LINE NO. 2. | | | | | LINE NO. 3. | | | | | LINE NO. 4 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length of Hose. | Diam. of Hose. | Diam. of Nozzle. | Indicated Pressure at Nozzle. | Discharge Per Minute. | Length of Hose. | Diam. of Hose. | Diam. of Nozzle. | Indicated Pressure at Nozzle. | Discharge Per Minute. | Length of Hose. | Diam. of Hose. | Diam. of Nozzle. | Indicated Pressure at Nozzle. | Discharge Per Minute. | Length of Hose. | Diam. of Hose. | Diam. of Nozzle. | Indicated Pres- |
| H. M. S. | H. M. S. | M. S. | Ft. | In. | In. | Lbs. | Gal. | Ft. | In. | In. | Lbs. | Gal. | Ft. | In. | In. | Lbs. | Gal. | Ft. | In. | In. | Lb |
| 10-27-30 | | | 150 | 3 | 1⅛ | | | 150 | 3 | 1⅛ | | | 150 | 3 | 1⅛ | | | | | | |
| 10-28-00 | 10-28-30 | 0-30 | " | " | " | 44.3 | 627 | Into Eastman Set. | " | " | 45.3 | 617 | Into Eastman Set. | " | " | 44.5 | 611 | | | | |
| 10-28-30 | 10-29-00 | 0-30 | " | " | " | 50.0 | 668 | " | " | " | 51.8 | 660 | " | " | " | 50.3 | 651 | | | | |
| 10-29-00 | 10-30-00 | 1-00 | " | " | " | 55.6 | 703 | " | " | " | 56.1 | 687 | " | " | " | 55.0 | 680 | | | | |
| 10-30-00 | 10-31-00 | 1-00 | " | " | " | 57.7 | 716 | " | " | " | 58.1 | 699 | " | " | " | 57.0 | 693 | | | | |
| 10-31-00 | 10-31-30 | 0-30 | | | | | | | | | | | | | | | | | | | |
| 10-31-30 | 10-32-00 | 0-30 | 150 | 3 | 1⅛ | 49.5 | 664 | 150 | 3 | 1⅛ | 51.3 | 657 | 150 | 3 | 1⅛ | 50.0 | 648 | | | | |
| 10-32-00 | 10-32-30 | 0-30 | " | " | " | 54.0 | 693 | " | " | " | 55.3 | 682 | " | " | " | 54.5 | 677 | | | | |
| 10-32-30 | 10-33-30 | 1-00 | " | " | " | 57.0 | 712 | " | " | " | 58.3 | 700 | " | " | " | 57.0 | 693 | | | | |
| 10-33-30 | 10-40-00 | 6-30 | " | " | " | 58.8 | 724 | " | " | " | 59.6 | 708 | " | " | " | 57.5 | 696 | | | | |
| 10-40-00 | 10-41-30 | 1-30 | " | " | " | 60.0 | 732 | " | " | " | 61.8 | 721 | " | " | " | 58.1 | 699 | | | | |
| 10-41-30 | 11-11-30 | | | | | | | | | | | | | | | | | | | | |
| 11-11-30 | | | 300 | 3 | 1½ | | | 300 | 3 | 1½ | | | 300 | 3 | 1½ | | | 300 | 3 | 1½ | |
| 11-12-00 | 11-13-00 | 1-00 | " | " | " | 75.6 | 400 | " | " | " | 70.7 | 387 | " | " | " | 65.0 | 371 | " | " | " | 7 |
| 11-13-00 | 11-14-00 | 1-00 | " | " | " | 86.8 | 429 | " | " | " | 82.0 | 417 | " | " | " | 85.2 | 425 | " | " | " | 8 |
| 11-14-00 | 11-15-00 | 1-00 | " | " | " | 93.5 | 445 | " | " | " | 88.8 | 434 | " | " | " | 93.9 | 446 | " | " | " | 9 |
| 11-15-00 | 11-17-00 | 2-00 | " | " | " | 100.0 | 459 | " | " | " | 94.8 | 448 | " | " | " | 101.3 | 463 | " | " | " | 9 |
| 11-17-00 | 11-18-30 | 1-30 | " | " | " | 102.2 | 465 | " | " | " | 97.8 | 455 | " | " | " | 104.8 | 471 | " | " | " | 10 |
| 11-18-30 | 11-19-30 | 1-00 | " | " | " | 104.4 | 470 | " | " | " | 105.2 | 472 | " | " | " | 109.1 | 481 | | | | |
| 11-19-30 | 11 21-00 | 1-30 | | | | | | " | " | " | 111.0 | 485 | " | " | " | 120.9 | 506 | | | | |
| 11-21-00 | 11-35-30 | | | | | | | | | | | | | | | | | | | | |
| 11-35-30 | | | 300 | 3 | | Siamesed | | 300 | 3 | 2 | | | 300 | 3 | | Siamesed | | 300 | 3 | 2 | |
| 11-36-00 | 11-36-30 | 0-30 | " | " | | with lines | | " | " | " | 81.5 | 1105 | " | " | | with lines | | " | " | " | 1 |
| 11-36-30 | 11-38-00 | 1-30 | " | " | | 2 and 3 | | " | " | " | 89.3 | 1158 | " | " | | 1 and 2 | | " | " | " | 8 |
| 11-38-00 | 11-39-00 | 1-00 | " | " | | into | | " | " | " | 91.0 | 1170 | " | " | | into | | " | " | " | 9 |
| 11-39-00 | 11-41-30 | 2-30 | " | " | | Eastman | | " | " | " | 94.6 | 1192 | " | " | | Eastman | | " | " | " | 9 |
| 11-41-30 | 11-49-00 | | | | | Set. | | | | | | | | | | Set. | | | | | |
| 11-49-00 | | | 300 | 3 | | Siamesed | | 300 | 3 | 2¼ | | | 300 | 3 | | Siamesed | | 300 | 3 | 2¼ | |
| 11-49-00 | 11-50-00 | 1-00 | " | " | | with lines | | " | " | " | 46.5 | 1091 | " | " | | with lines | | " | " | " | |
| 11-50-00 | 11-50-30 | 0-30 | " | " | | 2 and 3 | | " | " | " | 55.7 | 1198 | " | " | | 1 and 2 | | " | " | " | |
| 11-50-30 | 11-51-00 | 0-30 | " | " | | into | | " | " | " | 60.6 | 1251 | " | " | | into | | " | " | " | |
| 11-51-00 | 11-52-00 | 1-00 | " | " | | Eastman | | " | " | " | 63.5 | 1280 | " | " | | Eastman | | " | " | " | |
| 11-52-00 | 11-54-00 | 2-00 | " | " | | Set. | | " | " | " | 66.0 | 1305 | " | " | | Set. | | " | " | " | |
| 11-54-00 | 11-55-30 | | | | | | | | | | | | | | | | | | | | |
| 11-55-30 | | | 300 | 3 | | Siamesed | | 300 | 3 | 2½ | | | 300 | 3 | | Siamesed | | 300 | 3 | 2½ | |
| 11-56-00 | 11-56-30 | 0-30 | " | " | | with lines | | " | " | " | 39.6 | 1317 | " | " | | with lines | | " | " | " | |
| 11-56-30 | 11-57-30 | 1-00 | " | " | | 2 and 3 | | " | " | " | 43.8 | 1383 | " | " | | 1 and 2 | | " | " | " | |
| 11-57-30 | 11-59-00 | 1-30 | " | " | | into | | " | " | " | 47.6 | 1442 | " | " | | into | | " | " | " | |
| 11-59-00 | 12-00-00 | 1-00 | " | " | | Eastman | | " | " | " | 48.8 | 1462 | " | " | | Eastman | | " | " | " | |
| | | | | | | Set. | | | | | | | | | | Set. | | | | | |

Lines 1, 2, 3, from Hydrant at Post Office Square.
Lines 4, 5, 6, from Hydrant on Congress St., near Milk St.
In the last three sets of experiments, two Eastman Sets were used with three lines from each hydrant. Each Eastman Set includes 16' of 3¼" Hose.

# SALT WATER FIRE PIPE TEST

## At Post Office Square, Boston, Mass.

| NO. 2. | | | LINE NO. 3. | | | | | LINE NO. 4. | | | | | LINE NO. 5. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Indicated Pressure at Nozzle. | Discharge Per Minute. | Length of Hose. | Diam. of Hose. | Diam. of Nozzle. | Indicated Pressure at Nozzle. | Discharge Per Minute. | Length of Hose. | Diam. of Hose. | Diam. of Nozzle. | Indicated Pressure at Nozzle. | Discharge Per Minute. | Length of Hose. | Diam. of Hose. | Diam. of Nozzle. | | Discharge Per Minute (Approx) |
| . | Lbs. | Gal. | Ft. | In. | In. | Lbs. | Gal. | Ft. | In. | In. | Lbs. | Gal. | Ft. | In. | In. | | |
| ⅝ | | | 150 | 3 | 1¼ | | | | | | | | | | | | |
| " | 45.3 | 617 | Into | " | " | 44.5 | 611 | | | | | | | | | | |
| " | 51.8 | 660 | Eastman | " | " | 50.3 | 651 | | | | | | | | | | |
| " | 56.1 | 687 | Set. | " | " | 55.0 | 680 | | | | | | | | | | |
| " | 58.1 | 699 | | " | " | 57.0 | 693 | | | | | | | | | | |
| ⅝ | 51.3 | 657 | 150 | 3 | 1¼ | 50.0 | 648 | | | | | | | | | | |
| " | 55.3 | 682 | " | " | " | 54.5 | 677 | | | | | | | | | | |
| " | 58.3 | 700 | " | " | " | 57.0 | 693 | | | | | | | | | | |
| " | 59.6 | 708 | " | " | " | 57.5 | 696 | | | | | | | | | | |
| " | 61.8 | 721 | " | " | " | 58.1 | 699 | | | | | | | | | | |
| ½ | | | 300 | 3 | 1¼ | | | 300 | 3 | 1¼ | | | 300 | 3 | 1¼ | | |
| " | 70.7 | 387 | " | " | " | 65.0 | 371 | " | " | " | 72.6 | 392 | " | " | | | 388 |
| " | 82.0 | 417 | " | " | " | 85.2 | 425 | " | " | " | 84.4 | 423 | " | " | | | 424 |
| " | 88.8 | 434 | " | " | " | 93.9 | 446 | " | " | " | 93.0 | 444 | " | " | | | 442 |
| " | 94.8 | 448 | " | " | " | 101.3 | 463 | " | " | " | 98.7 | 457 | " | " | | | 457 |
| " | 97.8 | 455 | " | " | " | 104.8 | 471 | " | " | " | 101.3 | 463 | " | " | | | 464 |
| " | 105.2 | 472 | " | " | " | 109.1 | 481 | | | | | | | | | | |
| " | 111.0 | 485 | " | " | " | 120.9 | 506 | | | | | | | | | | |
| | | | 300 | 3 | | Siamesed | | 300 | 3 | 2 | | | 300 | 3 | | Siamesed | |
| " | 81.5 | 1105 | " | " | | with lines | | " | " | " | 76.3 | 1070 | " | " | | with lines | |
| " | 89.3 | 1158 | " | " | | 1 and 2 | | " | " | " | 85.8 | 1135 | " | " | | 4 and 6 | |
| " | 91.0 | 1170 | " | " | | into | | " | " | " | 88.5 | 1153 | " | " | | into | |
| " | 94.6 | 1192 | " | " | | Eastman | | " | " | " | 91.5 | 1173 | " | " | | Eastman | |
| | | | | | | Set. | | | | | | | | | | Set. | |
| ½ | | | 300 | 3 | | Siamesed | | 300 | 3 | 2½ | | | 300 | 3 | | Siamesed | |
| " | 46.5 | 1091 | " | " | | with lines | | " | " | " | 56.2 | 1205 | " | " | | with lines | |
| " | 55.7 | 1198 | " | " | | 1 and 2 | | " | " | " | 60.2 | 1247 | " | " | | 4 and 6 | |
| " | 60.6 | 1251 | " | " | | into | | " | " | " | 65.2 | 1298 | " | " | | into | |
| " | 63.5 | 1280 | " | " | | Eastman | | " | " | " | 66.7 | 1313 | " | " | | Eastman | |
| " | 66.0 | 1305 | " | " | | Set. | | " | " | " | 68.6 | 1331 | " | " | | Set. | |
| ½ | | | 300 | 3 | | Siamesed | | 300 | 3 | 2¼ | | | 300 | 3 | | Siamesed | |
| " | 39.6 | 1317 | " | " | | with lines | | " | " | " | | | " | " | | with lines | |
| " | 43.8 | 1383 | " | " | | 1 and 2 | | " | " | " | 47.4 | 1439 | " | " | | 4 and 6 | |
| " | 47.6 | 1442 | " | " | | into | | " | " | " | 50.0 | 1480 | " | " | | into | |
| " | 48.8 | 1462 | " | " | | Eastman | | " | " | " | 51.0 | 1493 | " | " | | Eastman | |
| | | | | | | Set. | | | | | | | | | | Set. | |

lines from each hydrant. Each Eastman Set includes 16' of 3½" Hose.

In the set of experiments with six 1¼" Nozzles, the total discharge for this set of experiments

'EST

November 13, 1898.

| 5. | | LINE NO. 6. | | | | | Total Discharge Per Minute. | Pressure at Hydrant Outlets, Line No. 1. | Loss of Pressure in Hose, Line No. 1, corrected. | Loss of Pressure per 100' under given discharge. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Discharge Per Minute (Approx) | Length of Hose. | Diam. of Hose. | Diam of Nozzle. | | Discharge per Minute (Approx) | | | | | |
| | | Ft. | In. | In. | | | Gals. | Lbs. | Lbs. | Lbs. | |
| | | | | | | | | | | | Pumps started at 10-27-30. |
| | | | | | | | 1855 | 109.0 | 63.7 | 43 | |
| | | | | | | | 1979 | 126.0 | 75.0 | 50 | |
| | | | | | | | 2070 | 134.5 | 77.9 | 52 | |
| | | | | | | | 2108 | 138.5 | 79.8 | 53 | |
| | | | | | | | | | | | Shut down. |
| | | | | | | | 1959 | | | | |
| | | | | | | | 2052 | | | | |
| | | | | | | | 2105 | | | | |
| | | | | | | | 2125 | | | | |
| | | | | | | | 2152 | | | | |
| | | | | | | | | | | | Shut down at 10-41-30. |
| | | 300 | 3 | 1¼ | | | | | | | Changing Hose Lines and Nozzles. |
| | 388 | " | " | " | | 388 | 2326 | 126.0 | 51.5 | 17.2 | Pumps started at 11-11-30. |
| | 424 | " | " | " | | 424 | 2542 | 140.0 | 52.2 | 17.4 | |
| | 442 | " | " | " | | 442 | 2653 | 147.7 | 53.2 | 17.7 | |
| | 457 | " | " | " | | 457 | 2741 | 152.8 | 52.8 | 17.6 | |
| | 464 | " | " | " | | 464 | 2782 | 157.0 | 53.8 | 17.9 | |
| | | | | | | | | Ft. at Hyd. Outlets P.O. Square. | Loss in Line, P. O. Sq. Inch Corrected | | |
| | | | | | | | | | | | Shut down at 11-21-00. |
| | | | | | | | | | | | Changing Nozzles. |
| Siamesed | | 300 | 3 | | Siamesed | | | | | | Pumps started at 11-35-30. |
| with lines | | " | " | | with lines | | 2175 | 134.5 | 52.0 | | |
| 4 and 6 | | " | " | | 4 and 6 | | 2293 | 148.3 | 58.0 | | |
| into | | " | " | | into | | 2323 | 151.5 | 59.5 | | |
| Eastman | | " | " | | Eastman | | 2365 | 156.9 | 61.3 | | |
| Set. | | " | " | | Set. | | | | | | Shut down at 11-41-30. |
| | | | | | | | | | | | Changing Nozzles. |
| Siamesed | | 300 | 3 | | Siamesed | | | | | | Pumps started at 11-49. |
| with lines | | " | " | | with lines | | 2296 | | | | |
| 4 and 6 | | " | " | | 4 and 5 | | 2445 | 128.5 | 71.8 | | |
| into | | " | " | | into | | 2549 | 136.7 | 75.1 | | |
| Eastman | | " | " | | Eastman | | 2593 | 143.0 | 78.5 | | |
| Set. | | " | " | | Set. | | 2636 | 148.2 | 81.2 | | |
| | | | | | | | | | | | Shut down at 11-54-00. |
| | | | | | | | | | | | Changing Nozzles. |
| Siamesed | | 300 | 3 | | Siamesed | | | | | | Pumps started at 11-55-30. |
| with lines | | " | " | | with lines | | | 119.5 | 78.9 | | |
| 4 and 6 | | " | " | | 4 and 5 | | 2822 | 128.0 | 83.2 | | |
| into | | " | " | | into | | 2922 | 140.7 | 92.1 | | |
| Eastman | | " | " | | Eastman | | 2955 | 146.0 | 96.2 | | |
| Set. | | " | " | | Set. | | | | | | Shut down at 12-00. |

f" Nozzles, the discharge from lines 5 and 6 is approximate, as no pressures were taken at the Nozzles, therefore the
f experiments is approximate.

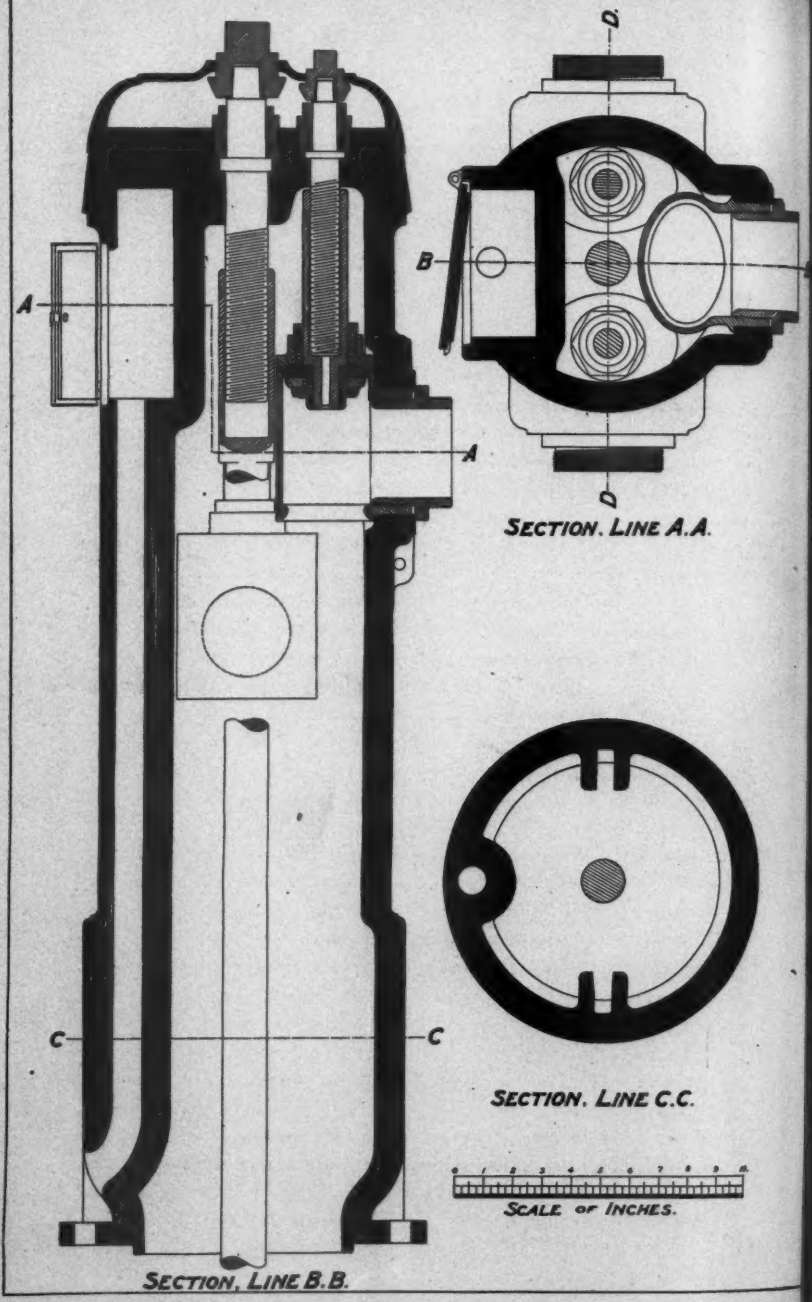
thorough methods of testing and maintenance that are provided for the regular circuits; any trouble occurring, such as a break, short circuit or ground escape, is indicated at the central office, and the fault may be located and repaired with facility. Two of the five conductors in the cable are utilized and a metallic circuit is established, the others being held in reserve for any emergency that may arise.

Each hydrant is equipped with a break key whereby the code signals can be transmitted to the Fire Boat station, where they are sounded on a gong. In addition, portable instruments (consisting of Morse key and sounder), can be connected into circuit by means of jack plugs, at all hydrants and at boat stations; in this way any single hydrant or all the hydrants may be placed in communication not only with the Fire Boat, but with the central office as well, giving a service that extends far beyond the possibilities of a simple signal code.

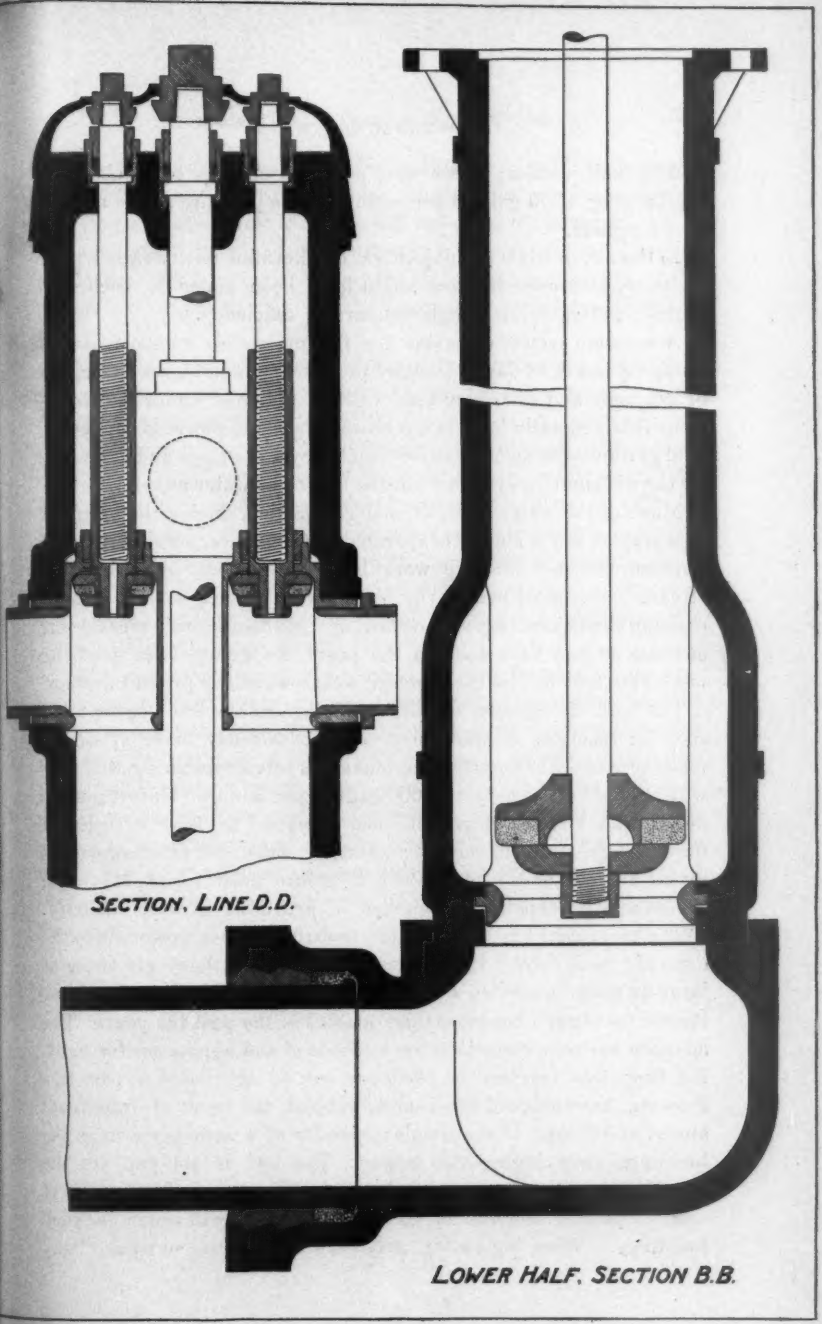
Two of the portable instruments are carried on each boat, one to be used at the boat station, and the other at the hydrants.

This system, as established, must prove in its limited field of action a valuable addition to the other facilities of the city for fighting fire; it is a distinct advance in one important respect, viz., in the application of pumping power in large units, in connection with an unlimited supply of water, ensuring the ability to furnish fire streams of sufficient power at all times, and of unusual size and power when required.

A test of the system recently made at a distance of one-half mile from the water front, with one Fire Boat in service, proved very satisfactory. The following are some of the results obtained: Two streams, each of 1,500 gallons per minute, were played simultaneously through 2½-inch nozzles, with a nozzle pressure of 50 pounds, three lines of 3-inch hose, each 300 feet long, being siamesed for each stream; such a deluge of water would be used to best advantage at long intervals, yet the ability to do work of this kind is invaluable, when the necessity arises very great interests are at stake. Another trial was made with 1¾-inch nozzles, six independent streams being played each through 300 feet of 3-inch hose with a total discharge of 2,760 gallons per minute, the nozzle pressure exceeding 100 pounds, probably too high for best practical results. A third trial was made using three separate lines of 3-inch hose




DETAILS OF BACHELDER HYDRANT.




Details of Bachelder Hydrant.

and 1¾-inch nozzles; three very powerful streams were obtained discharging 2,200 gallons per minute with a pressure at the nozzles of 61 pounds.

In the above trials the object was to determine power rather than capacity, and more streams might have been added in each case without falling below a high standard of efficiency.

A separate system of mains for fire protection with permanent pumping power of large capacity promises a much greater degree of economy and efficiency than can be obtained under the conditions that generally exist in our cities, where the power is applied by a large number of comparatively small movable pumps and the mains of the distribution system form the source of water supply.

Much of the water used, in modern practice, during the progress of a serious fire is simply evaporated in the flames, serving no good purpose, the only effective work being often done by a very few streams; this must necessarily be the case, to some extent. Under existing conditions very serious fires or "conflagrations" must occur at times as they have done in the past; the greater the need the more apparent will be the inherent weakness of the present system.

The limit in capacity of the modern movable fire engine must soon be reached, if that point has not already been attained; today propellers or horseless engines are in service weighing nine tons with a nominal capacity of 1,600 gallons per minute. Unfortunately distribution systems have not been designed to bear so heavy a burden with uniform success; points of weakness exist where the mains are old and inadequate and failure must result, at times, unless a large expense is incurred in providing greater capacity.

The movement has been steadily towards greater power since the days of "hand tubs," the nozzles in general use today are twice as large as those in service a few years ago, while the capacity of the largest "steamer" has more than doubled in the past ten years. The advance has been general in the methods of and appliances for fighting fire; this increase in efficiency can be attributed in part to a growing knowledge of the general subject, the result of intelligent study, and in part to the simple necessity of a stronger arm as the buildings grew higher and larger. The end is not yet, for the future will see a great increase in tall buildings, and the majority of fires, in certain sections at least of our cities, will occur in such buildings. Wise legislation may frown upon the extreme "sky

scraper," but future conditions demanding, for safety, more power than is now available, are inevitable. Modern fire-proof construction will improve the conditions, but will not solve the problem.

A city largely surrounded by water, as is the "down town" section of Boston, offers an inviting field for an independent system of fire protection. Some of the essential features of such a system would be:

Connecting mains, in the streets, of moderate size; permanent pumping stations of large capacity, operated perhaps by electricity or compressed air; post hydrants at short intervals; direct connections to standpipes inside of buildings; stand-pipes outside of buildings, both in front and rear, with means for connecting hose at the street level and with outlets at different levels, making them in effect permanent water towers; a moderate pressure always upon the system with the ability to instantly apply full fire pressure; a complete electrical signal service; emergency connections for Fire Boats; the use of existing distribution system as an auxiliary to some extent.

The above conditions would mean the ability to concentrate very large quantities of water at any desired point in the system, and the ability to reach the tops of tall buildings and to uniformly furnish powerful fire streams; a saving of time could be made in the first precious moments of getting to work, which cannot be over-estimated; water could be supplied for street sprinkling and for flushing sewers to great advantage; a very great reduction could be made in the cost of extensions and renewals of the existing distribution systems when the need of providing capacity for fire purposes no longer exists.

# THE USE OF STEEL FOR WATER MAINS.

BY L. M. HASTINGS, C. E.

[*Read January 11, 1899.*]

For more than two hundred years, cast iron has been used as a material for the manufacture of water pipes, and, during the latter part of this period, to the practical exclusion of all other materials. In spite of numerous attempts to find a better or cheaper substitute; wood, cement, lead, glass, wrought iron and steel,—cast iron still holds its supremacy for general use in a water works system. Nothing has yet been discovered or devised which at present warrants any belief in its being displaced for that purpose,—so that no one, either iron founders, mine owners or water works men having large systems of cast iron pipe in charge, need have any feeling of alarm at what may be said regarding the use of steel for water pipes.

While there are situations and circumstances under which steel pipe may be used with advantage, and with a probable saving of money, it is undoubtedly true that the "situations and conditions" in which this material may with advantage be used, are comparatively few. Its field of usefulness is and probably will remain a limited one.

Steel seems best adapted for use:

First. For the larger sizes of mains, say from 24-inch diameter upwards. At about this size the relative cost begins to be in favor of cast iron.

Second. For what may be called leading mains in outlying districts—force mains, and similar work where not likely to be disturbed or tapped.

Third. As conduits in remote regions difficult of access, its lightness and ease of transportation fitting it especially for this use.

Under these conditions the principal advantages in the use of steel are:

First. Economy in first cost. This is in many instances the controlling factor in the case. At the prices which have prevailed for the last six or eight years, quite a substantial saving can usually be made by the use of steel, varying of course, with the size of

the pipe, the market and local conditions, as to its delivery and laying. Thus at Rochester, N. Y., the cost of a 36-inch cast iron pipe in 1892 was $6.21 per foot, and the cost of 38-inch steel pipe $5.84 per foot, a saving of 6 per cent. on the cost of cast iron.

At Cambridge, Mass., in 1895, on comparing bids for 40-inch pipe, it was found that a saving of 31½ per cent. could be made by using steel. (See correction made later.)

At New Bedford, Mass., in 1896, with a 48-inch pipe, an estimated saving of 23 per cent. was made by using steel.

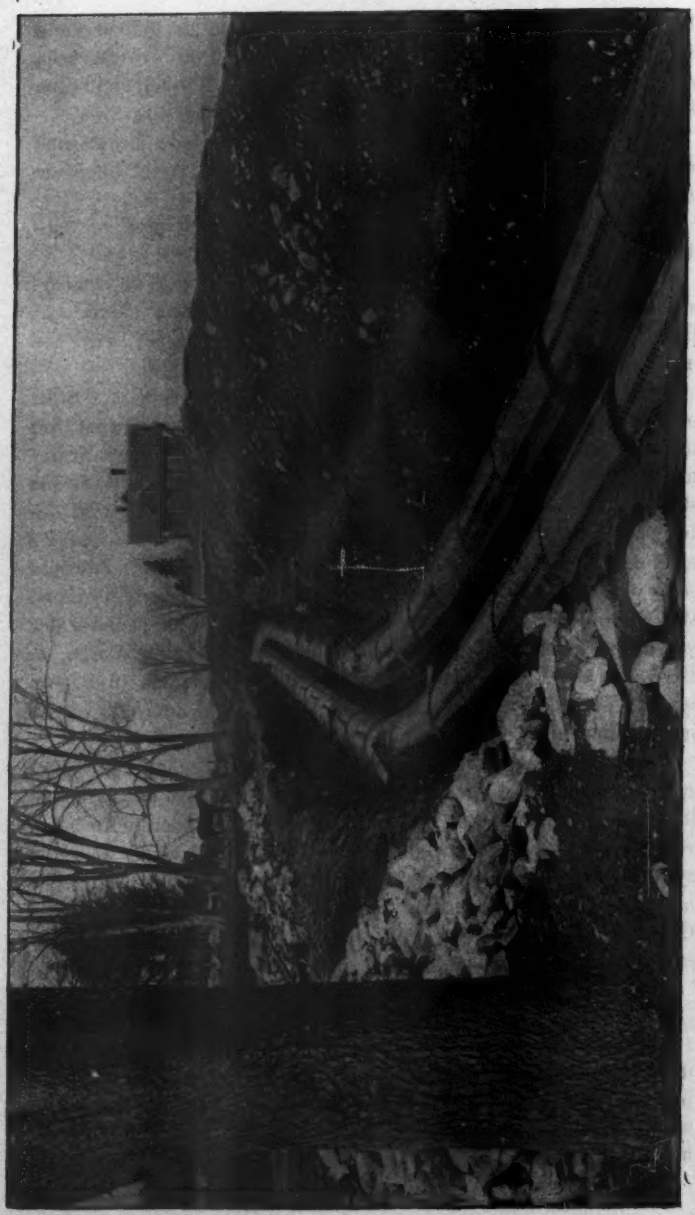
At Minneapolis, Minn., in 1897, with a 50-inch pipe on comparative bids received, a saving of 28 per cent. was made. At Duluth, Minn., in 1897, an estimated saving of 33 per cent. was made by using steel.

Second. Less liability of breakage while in service. Steel plate is undoubtedly a much more reliable material than cast iron to resist tensile strains and the shocks incident to its use in water mains. Being so much more uniform in its texture and tensile strength, with vastly less liability to have flaws and structural defects of a dangerous character,—a much smaller factor of safety can be used and a lighter and more reliable pipe made. It would seem to be practically impossible that, with a properly designed steel pipe, disastrous breaks should occur, such as happened a few years ago in the 48-inch main of the Boston Water Works, on Beacon Street, or last year, 1898, in the 48-inch main in Brooklyn, N. Y., when a large amount of damage was done; or again in St. Louis and Philadelphia in 36-inch mains.

Third. Its adaptability for special situations when the use of cast iron would be attended with risk, or excessive cost. It not infrequently happens that a pipe line is obliged to cross an intervening river, ravine or deep cut, by a bridge or by an inverted syphon, where vibration or excessive pressure would render the use of steel more advisable than that of cast iron. Its use in Ogden, Utah, Minneapolis, Minn., Cambridge, Mass., and Syracuse, N. Y., are illustrations in point.

## DISCHARGING CAPACITY.

In comparing the relative costs of steel with cast iron pipe, it is important to know the actual discharging capacity of each kind of pipe of the same diameter. With reference to the discharging capacities of cast iron pipe of varying sizes and under different heads, a great mass of experimental data has been accumulated by



CURVED PIPE—CAMBRIDGE, MASS.

painstaking experimenters both American and foreign. This great mass of data, however, unless used with the greatest caution and skill will give results so various as to be positively bewildering to the ordinary seeker after reliable facts. It is only by a skillful selection and use of the formula and coefficients derived under conditions similar to that in hand that reliable figures can be obtained.

The remark of the late James C. Duane of New York, that "the degree of accuracy obtainable from any formula is dependent on the more or less (usually less) scientific guess at the value of a modifying coefficient appropriate to each case," seems extremely pertinent in this connection.

A great many of the formulæ and tables given in text and hand books for finding the delivery of pipes, are for "new, clean and straight" pipe; whereas, in actual practice, these conditions are seldom met with, and in but a few years the conditions as regards smoothness of surface, and consequent delivery, are radically changed.

The gauging test of Mr. Duane on the delivery of a 48-inch pipe in New York is interesting, as illustrating this. The pipe was cast iron, uncoated, and on being tested for delivery soon after laying was found to deliver a quantity equivalent to that computed by the well-known Chezy formula, $V = C\sqrt{R\,S}$, when C= 135.00. Seven years later the same pipe was tested again and found to give a value of C=96, a reduction of about 30 per cent. (See Transactions, American Society Civil Engineers, Vol. 1893.)

Substantially the same result has been observed by Mr. FitzGerald in a 48-inch pipe on the line of the Sudbury River Conduit, when value of C as found by Mr. Stearns in 1884 to be from 139.94 to 143.16—in 1896 it was found to be about 108.00. (See Transactions American Society Civil Engineers, Vol. 35, 1896.)

The test made by Mr. Coffin on the friction in force mains as given in Journal of New England Water Works Association, June, 1896, shows in most cases a similar tendency. Mr. Forbes of Brookline, President of this Association, in a paper read in 1892 on tests made on a 16-inch force main 18 years old, obtained results giving a value to C of 93 with V=1.15 to 1.97 feet per second.

Mr. A. L. Adams, in a paper read September, 1898, American Society Civil Engineers, gives values of C for cast iron pipe for all except very low velocities, as follows:

CURVED PIPE OVER HAIL ROAD.

| | Clean Pipe. | Rough Pipe. |
|---|---|---|
| 30-inch..... | C=129.00 | C=97. |
| 36- " ..... | C=133.00 | C=101. |
| 42- " ..... | C=136. | C=105. |
| 48- " ..... | C=138. | C=108. |
| 54- " ..... | C=140. | C=110. |
| 60- " ..... | C=142. | C=112. |
| 66- " ..... | C=144. | C=114. |
| 72- " ..... | C=146. | C=116. |

The observed flow of the 30-inch conduit from Stony Brook to Fresh Pond, Cambridge, shows a marked diminution in the twelve years since it was laid. I regret that no exact measurement has been possible to determine the amount of this loss in flow.

From this it would seem that a somewhat larger allowance for tuberculation and roughened surfaces should be made than is often done. In the Kutter formula, n=.0135, and in large sizes and medium velocities, C=100 to 110, may be allowed. This will give results a little smaller than E. S. Gould's formula, adopted from Darcy, using the coefficients for rough pipe given in his little book on "Practical Hydraulic Formulæ."

Compared with clean cast iron pipe, steel pipe, owing to its construction and the inequalities in its inner surface, must at first be at somewhat of a disadvantage as regards discharging capacity. Owing, however, to the more rapid fouling of the cast iron pipe, this in a measure disappears in time. For determining the flow in riveted pipe, comparatively little reliable data at present exists.

Some data has been obtained by Hamilton Smith in California.

Mr. Herschel has made some careful tests in the New Jersey pipes of 42-inch and 48-inch diameter. (See "115 Experiments on the Carrying Capacity of Large Riveted Steel Conduits," 1897), which have been well adapted for use by Prof. Merriman in his "Treatise on Hydraulics" (Ed. 1897.)

From this it would appear that C=98 would apply to 48-inch pipe of steel four years in use for velocities over 2 feet per second.

Mr. Emil Kuichling has also made some careful gaugings of the flow in the Rochester, N. Y., pipe. (See "Annual Report of Executive Board," 1895, 1896, 1897.) For 38-inch pipe four years old, Mr. Kuichling obtained C=113.58 with V=1. ± C=115.38, V=3.25, and C=109.25 and 106.50 V=3.75. Mr. Kuichling's test of the old conduit, in use sixteen years, gave for the 36-inch pipe C=85.00 and for the 24-inch, C=83.00.

A test made on a 14-inch pipe of steel in New Westminster, B. C., in 1896, gave C=73 for V=1.35.

Mr. A. L. Adams, at Astoria, Ore., in testing a compound 14-inch and 16-inch line, obtained C=112.30. Mr. Adams gave in his paper in 1898, above referred to, as a suggested value of C for riveted pipe; for clean pipe C=111, rough pipe, 20 per cent. less, or C=89.00. These values seem to me about an average, and can safely be used.

Steel pipe, as commonly made, consists of an inside and an outside course, alternating; the inside diameter of the outside course being just twice the thickness of the plate larger than the inside diameter of the inner and smaller course. Some attempt to reduce the resulting loss of head has been made by making the courses tapering, with a large and small end, the small end of one plate fitting into the large end of the next plate. The small end being placed in the direction of the flow, and so a gradual reduction in diameter or taper being made. If the results obtained by Mr. Herschel are correct, this does not accomplish the object sought, for, as demonstrated by Prof. Merriman, in his "Treatise on Hydraulics," the sudden enlargement of section at the end of the plate increases the loss of head more than the reduction of the section would if the plates were reversed, or if it were made with inside and outside courses.

Mr. Herschel's friction coefficients are generally larger for pipe with taper joints than for pipe with cylinder joints.

Suppose, now, we apply the figures by way of illustration, to the Cambridge, Mass., pipe, 40-inch diameter, already referred to. Assume that the value of C for cast iron be 105.00, for steel to be 90.00, this would require the steel pipe to be 42 inches in diameter to deliver the same amount of water as a 40-inch cast iron, or to produce the same loss by friction head. The thickness of the plate used was 5-16 inch. The increased amount of metal in a 42-inch pipe, over that in the 40-inch pipe used, will be about 7.5 pounds, allowing for laps, rivets, etc. The pipe, as built, took 3,711,000 pounds of metal, and cost in the ground—including all special work, extras, etc., \$116,119.77, or $3\frac{13}{100}$ cents per pound. The length was 24,133 feet, or \$4.81 per foot. As valves and special fittings were all 36-inch, no increased cost would have been incurred for these, in making it 42-inch, and it seems fair to estimate it by the pound at the price actually paid, i. e.: .0313 x 7.50 =\$.235 per foot increased cost, or about 5 per cent. on \$4.81, so that the figures given in the first of this paper as a saving of $31\frac{1}{2}$

per cent. should strictly be 26½ per cent. for pipe of equivalent capacity.

The proposed attempt to reduce the friction in a steel pipe by the engineers in charge of the works projected at Coolgardie, Australia, will be watched with great interest.

Owing to the great length of the line, some 328. miles, and the high price of coal in that region, the matter of friction became a very serious one. It is now proposed to have no riveting at all on the pipe, which is to be 30 inches in diameter, its entire length. The plate is to be rolled so as to make two half sections about 28 feet long; the edges of these plates are slightly upset and inserted into the slots of a "locking bar" which are then pinched together firmly, closing the two horizontal seams. The vertical or roundabout joints are to be made up with a wrought iron sleeve with lead caulked in place. By thus reducing the probable friction head, the value of C. was taken as 98.00 in the estimated delivery of this pipe. This is probably the largest work of the kind ever attempted. (See Engineering News, February 10, 17, October 13 and December 29, 1898).

PROTECTIVE COATING.

The thickness of the plates from which the steel pipe is made, is so much less than cast iron, that a more adequate protective coating than that usually given to cast iron, has been deemed necessary. Asphalt in some form may be said to be the base of most of the preparations now proposed for this purpose. There can be no doubt, I think, of its great value for this use. The different mixtures and compounds used for coating may all be classed by the two methods of applying it to the pipe.

By the first, the mixture is heated in a large upright tank, and the pipe, after being thoroughly cleaned and heated, is dipped into the tank, and after remaining long enough to become of the temperature of the mixture, it is withdrawn and allowed to cool, when the pipe is ready for shipment. A very interesting description of this process, using what is called "Mineral Rubber," analysis, test of materials, etc., with illustration, is given in the Annual Report of Mr. Cappelen, City Engineer of Minneapolis, Minn., for 1897.

By the second plan, the pipe after heating, is dipped vertically into the coating material, and then placed in an oven where it is baked until the coating forms a kind of japan or enamel, covering the pipe. The 40-inch pipe line laid in 1896, in Cambridge, was

coated by this method, using the "Sabin coating," so called—as made by E. Smith & Company of New York.

In order to determine experimentally, something of the value of this coating as a protective agent, a number of cast iron, steel and wrought iron plates were obtained and put, some in water, some in sand and some in clay soil. Those in the water were put in the draught conduit at the engine house, so that they were subject to much the same conditions as the interior of a pipe. The pieces were carefully weighed before being placed, and then after a little over a year's test, were taken out and examined, and weighed over again. The result is show in the following statement:

TRIAL TESTS OF UNPROTECTED AND PROTECTED METAL UNDER VARIOUS CONDITIONS AT CAMBRIDGE, MASS.

| Kind of metal. | Coating. | Situation of pipe. | Original Weight. | Weight when examined. | Percentage of increase. | REMARKS. |
|---|---|---|---|---|---|---|
| | | | lbs. oz. dr. | lbs. oz. d. | | |
| W'rt Iron | Uncoated.... | Water.... | 4 15 1 | 5 1 4 | 1.5 | Badly tuberculated and rusted; worst of lot. |
| " ..... | " ..... | " .... | 4 6 12 | 4 9 0 | 3.1 | Badly tuberculated and rusty. |
| " ..... | " ..... | Sand..... | 4 15 14 | 5 1 8 | 2.0 | Very rusty; sand adhered to plate. |
| " ..... | " ..... | Clay..... | 4 5 10 | 4 6 4 | 0.89 | Rusty. |
| Steel.... | " ..... | Water.... | 4 7 11 | 4 8 8 | 1.1 | Rusty and tuberculated, but not as badly as iron. |
| " ..... | " ..... | " .... | 4 5 0 | 4 6 8 | 2.1 | Rusty and tuberculated. |
| " ..... | " ..... | Sand..... | 4 5 6 | 4 5 12 | 0.54 | Much rust. |
| " ..... | " ..... | Clay..... | 4 9 3 | 4 9 8 | 0.4 | Somewhat rusty. |
| Cast Iron. | " ..... | Water.... | 20 2 8 | 20 6 0 | 1 | Badly rusted and tuberculated. |
| " .. | " ..... | " .... | 19 6 8 | 19 9 8 | 0.96 | Badly rusted and tuberculated. |
| " .. | " ..... | Sand..... | 19 10 13 | 20 0 4 | 1.7 | Badly rusted; sand adhered to plate. |
| " .. | " ..... | Clay..... | 19 13 10 | 19 13 8 | ..... | Somewhat rusty. |
| Wr't Iron | Single coat... | Water.... | 4 14 11 | ..... | ..... | In good condition; no rust. |
| " ..... | " ..... | " .... | 4 9 6 | ..... | ..... | Good condition. |
| " ..... | " ..... | Sand..... | 4 9 4 | ..... | ..... | Fairly good condition; some rust spots. |
| " ..... | " ..... | Clay..... | 4 13 11 | ..... | ..... | Good condition; little rust. |
| Steel.... | " ..... | Water.... | 5 11 11 | ..... | ..... | Fairly good, some little rust. |
| " ..... | " ..... | " .... | 5 13 2 | ..... | ..... | Fairly good. |
| " ..... | " ..... | Sand..... | 4 11 0 | ..... | ..... | Fairly good. |
| " ..... | " ..... | Clay..... | 5 5 8 | ..... | ..... | Fairly good. |
| Cast Iron. | " ..... | Water.... | 19 2 15 | ..... | ..... | Fairly good; little rust. |
| " .. | " | Sand..... | 19 4 6 | ..... | ..... | Good condition. |
| " . | " ..... | Clay..... | 20 8 2 | ..... | ..... | Good. |
| Steel.... | Double coat.. | Water.... | 5 11 13 | ..... | ..... | In good condition. |
| " .... | " ..... | " .... | 5 6 8 | ..... | ..... | Good condition. |
| " ..... | " ..... | Sand..... | 7 2 12 | ..... | ..... | Very good condition; bright and clean. |
| " ..... | " ..... | Clay..... | 5 8 10 | ..... | ..... | Very good. |

After this examination, the pieces were put back in the same places for examination the second year. Some of the pieces placed in the water were lost, but those found showed the same general characteristics as at the first examination, but with no increase of weight.

This experiment indicated that unprotected, the wrought iron plate was most affected by oxidation under the three conditions tried; that steel plate was affected less, and cast iron the least of any. It showed also that the protective coating was efficient in keeping all the metals tried in good condition. The superiority of the coating over that ordinarily applied to cast iron was also demonstrated by examination of the line of pipe laid in the reservoir at Payson Park. Some 800 feet of 40-inch pipe ¼ inch thick were laid on the bottom of the reservoir, and were kept constantly covered with water for two years. When the water was drawn down, the steel pipe was in good condition, and the coating bright and sound. All the cast iron pipe and fittings, coated with the ordinary coal tar dip, were badly rusted and tuberculated.

Mr. Isaac W. Smith, in a paper read in 1898, before the American Society of Civil Engineers, states that at Portland, Oregon, the first supply put in, 28 years ago, has an 18-inch main made of No. 6 plate iron, coated with asphalt. "It now appears perfectly clean and sound; a part of this pipe being still in use, under 90 pounds pressure."

The 30-inch main laid there twelve years ago was also found clean and in good condition.

## DURABILITY.

The question of the durability of steel pipe is one about which some uncertainty exists, as experience with its use for long terms has not yet been extensive enough to warrant any definite conclusions. The record of wrought iron in California, with the water and soil there found, has been long and satisfactory. The same may be said of the wrought iron pipe in Rochester, N. Y.

Some question has been raised as to the relative resistance to corrosion of wrought iron and steel. My own experience and observation, already referred to, would indicate that, of the two metals, steel was the superior. Exactly what the difference in life of the two metals, cast iron and steel, may be taken to be, it is not

possible now to state; but while it may be conceded that with its greater thickness and probable less tendency to corrosion, cast iron will, in most soils and water, last longer than steel—although this has not yet been proven,—this difference does not seem likely to be great enough to affect disastrously the many advantages possessed by steel for the purposes as before defined.

The following is a list of such pipe lines as I have been able to learn of, with data as to construction:

| Locality. | Date. | Material. | Coating. | Length. Miles. | Diameter. | Thickness. |
|---|---|---|---|---|---|---|
| Rochester, N. Y. | 1873–4 | Iron Plate | Asphalt | 9.62 | 36" | $\frac{3}{8}$" |
| " " | 1873–4 | " " | " | 2.92 | 24" | $\frac{1}{4}$" to $\frac{3}{8}$" |
| " " | 1893–4 | Steel Plate | Sabin Coating | 26.51 | 36" | $\frac{1}{4}$" to $\frac{3}{8}$" |
| E. Jersey Water Co. | 1892 | " " | Asphalt | 21.00 | 48" | $\frac{1}{4}$" to $\frac{3}{8}$" |
| " " " " | 1892 | " " | " | 5.00 | 36" | (?) |
| " " " " | 1897 | " " | " | 5.00 | 48" | |
| New Westminster, B. C. | 1892 | " " | " | 13.40 | 14" | |
| Portland, Ore | 1893 | " " | | 24.00 | 33" & 42" | 0.213" |
| " " | 1894 | " " | | | 35" & 42" | 0.134" |
| Astoria, Ore | 1895 | " " | Cal. Asphalt | 3.00 | 16" | 0.109" |
| " " | 1895 | " " | " | 1.00 | 14" | $\frac{5}{16}$" & $\frac{1}{4}$" |
| Cambridge, Mass | 1895 | " " | Sabin Coating | 4.57 | 40" | |
| Allegheny, Pa. | 1896 | " " | " | 10.00 | 60" | |
| Pittsburgh, Pa. | | " " | Asphalt | 1.39 | 50" | $\frac{5}{8}$", $\frac{3}{8}$", $\frac{7}{16}$" |
| New Bedford, Mass | 1896 | " " | " | 8.05 | 48" | $\frac{1}{2}$" |
| Spokane, Wash. | 1894 | " " | " | 4.00 | 42" | No. 7 gage |
| " " | 1899 | " " | " | 4.00 | 24" | No. 7 gage |
| Syracuse, N. Y. | 1893 | " " | Cal. Asphalt | 1.21 | 54" | $\frac{5}{8}$" |
| Brooklyn, N. Y. | 1896 | " " | | 15.00 | 66" | |
| Duluth, Mich | 1896 | " " | Asphalt | 3.00 | 42" | $\frac{1}{4}$ to $\frac{1}{2}$" |
| " " | 1896 | " " | " | 0.25 | 60" | $\frac{1}{2}$" |
| Ogden, Utah | | " " | Cal. Asphalt | 0.87 | 72" | |
| Minneapolis, Minn. | 1897 | " " | Mineral Rubber | 6.49 | 50" | $\frac{5}{16}$ & $\frac{3}{8}$" |
| Coolgardie, Austr'a. | Proposed | " " | Asphalt | 328.00 | 30" | |

# WATER PIPES ON METROPOLITAN WATER WORKS.

BY DEXTER BRACKETT, C. E., ENGINEER DISTRIBUTION DEPARTMENT METROPOLITAN WATER BOARD.

[*Read January 11, 1899.*]

Mr. President and fellow members: In a moment of weakness I promised the President that I would say something in regard to the pipes used in connection with the Metropolitan Water Works; but I am very much afraid that I shall not succeed in adding much of value to what most of you already know in regard to the subject, as our work so far as the use of pipes is concerned, does not present any radical changes from customary usage.

During the past few years pipes made of steel plates from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in thickness have, as you all know, been used to a considerable extent for mains of large size, instances of which will be brought to your attention this afternoon. The advisability of using this class of pipe for our work was carefully considered, as many of our mains were to be of large size. The thinness of metal in the steel pipes renders the length of life of the pipes very much dependent upon the ability of the coating to prevent corrosion of the iron, and where pipes are to be laid in public streets, as ours were to be, and the coating constantly exposed to injury on account of public work of various kinds, I do not think that it would be possible to protect the coating from damage, except at a very great cost. If the coating is not thoroughly protected from injury, there is, to my mind, a very serious doubt as to whether it is advisable to use so thin a material.

As you know, Boston and vicinity are not noted for the regularity of street lines, and the frequent angles required in the pipe lines to conform to the changes in direction, both horizontal and vertical, many of which, due to underground objects, were only discovered

when the trenches were opened, would have delayed the work and increased its cost. It would also have been impracticable to have left the pipes exposed in the streets for any considerable distance in order to apply a water pressure test, which is absolutely necessary with riveted pipes.

For this, and perhaps some minor reasons, it was decided to use cast iron as the material for our pipes. A 36″ riveted steel pipe about 40 feet in length was used in crossing over a water course.

The next question to be determined was the thickness of metal to be used in the pipes. On an order for a few hundred tons of pipes, the question of thickness and consequent weight is not of much importance, but when 75,000 tons of pipes are to be furnished, the thickness of the pipes as affecting the cost becomes a question for careful consideration. The thickness of cast iron water pipes used in different places varies very largely, and the tendency during the past ten years has, I think, been toward the use of thinner pipes, particularly for the larger sizes. When pipes were cast horizontally, and the tops of the castings were in many instances one quarter of an inch thick and the bottoms three quarters, a much larger margin of safety was necessary than at the present time when the thickness at different points seldom varies more than a few hundredths of an inch. I think that the thickness of pipes has been very largely based upon the practice of former years, when the work at the foundry was not done with the precision which now obtains.

The thickness of metal which it is necessary to use in cast iron pipes, to withstand the static pressure due to the elevation of water in a reservoir, is for the smaller sizes of pipes very much less than the thickness used. For example, assuming a factor of safety of five for the strength of the iron the thickness required for a 6-inch pipe to withstand a pressure of 100 pounds would only be about $\frac{1}{10}$ of an inch, that is with no allowance for water hammer, but simply for a static pressure of 100 pounds per square inch, the thickness of metal needed would be $\frac{1}{10}$ of an inch. But as you all know, a cast iron pipe of that thickness could not be made nor handled. In determining the proper thickness for cast iron pipes allowance must be made for the pressure due to water hammer, for inequality in manufacture, for safety in handling, and for deterioration. After a careful study of the subject it was decided to use the following formula in determining the thickness of the several sizes of pipes to be used:

$$t = \frac{(p + p')r}{3300} + 0.25$$

r = the radius of the pipe in inches.

p = the static pressure in pounds per square inch.

p′ = the allowance in pounds for water hammer.

0.25 = allowance for inequality in manufacture, deterioration, and safety in handling.

p′ = 70 for sizes from 60″ to 42″ inclusive.

p′ = 75 for 36″ pipe.

p′ = 80 for 30″ pipe.

p′ = 85 for 24″ pipe.

p′ = 90 for 20″ pipe.

p′ = 100 for 16″ pipe.

p′ = 110 for 12″ pipe.

p′ = 120 for sizes from 10″ to 3″.

THICKNESS OF CAST IRON PIPES.

| Class. | A | B | C | D | E |
|---|---|---|---|---|---|
| Head, Ft. | 115 | 150 | 200 | 250 | 300 |
| Pressure, Lbs. | 50 | 65 | 87 | 109 | 130 |
| Diameter, Inches. | Thickness in Inches. | | | | |
| 4 | | | | .40 | .45 |
| 6 | | | | .46 | .50 |
| 8 | | | | 52 | .55 |
| 10 | | | | .60 | .63 |
| 12 | | .57 | .61 | .65 | .69 |
| 14 | | .61 | .65 | .70 | .75 |
| 16 | | .65 | .70 | .75 | .81 |
| 20 | | .73 | .79 | .85 | .92 |
| 24 | | .80 | .87 | .95 | 1.03 |
| 30 | | .92 | 1.00 | 1.10 | 1.20 |
| 36 | .93 | 1.03 | 1.13 | 1.25 | 1.36 |
| 42 | 1.01 | 1.14 | 1.27 | 1.40 | |
| 48 | 1.15 | 1.25 | 1.40 | 1.55 | |
| 54 | 1.23 | 1.35 | 1.53 | | |
| 60 | 1.35 | 1.50 | 1.70 | | |

This formula gives thicknesses which are somewhat less than have been used on the Boston works, and in many places in this vicinity. The cost of the pipes used on the Metropolitan works has been more than $200,000 less than it would have been had they been made of the thicknesses used on the Boston works. Up to the present time 72,900 tons of pipes and 2,746 tons of special castings have been purchased for the work, and of this quantity more than 80 per cent have been of sizes from 36 inches to 60 inches in diameter.

The form of sockets used is the common one, being slightly less deep than those used on the Boston works and deeper than the shallow sockets used in Providence and Newton. For crossing under the Charles and Mystic rivers 36-inch pipes were used, having a special form of socket and of extra thickness, to allow for the deterioration in the salt water. These pipes are 1.65 inches in thickness, and weigh 677 pounds per linear foot, or 8,500 pounds per length. For these pipes three types of joints were used. The first differed from the ordinary pipe joint by substituting three turned grooves for the usual single groove in the bell. These grooves were for the purpose of holding the lead more securely. In the second type the bell was the same as in the first, but the spigot was smoothly turned with a straight taper to a standard pattern, so as to be interchangeable. After inserting one of these tapering spigots in the bell of a pipe, and running the joint with lead, the spigot could be withdrawn, and when again inserted would make a tight joint. The third type was a flexible ball-and-socket joint. The spigot end of the pipe was made larger and thicker than in ordinary pipes, and turned truly spherical. On the inner surface of the bell, 8 inches in from the end, there is a raised ring 1 inch in width, which is turned to fit the spherical surface of the spigot end. In the bell between this ring and the end of the pipe there are five grooves to hold the lead, of which about 280 pounds were used for each joint. This joint permitted a deflection of about one in ten, and was designed so that the whole deflection could take place without having any portion of the spigot end project into the waterway.

### TESTING OF MATERIAL.

As the pipes form a very important part of the work, much care has been given to the details of their manufacture. With every

day's work at each pipe shop four test bars were made and broken to determine the transverse strength of the iron used. This test was used rather than the test of the tensile strength of the iron, as very hard and brittle iron will often show a high tensile strength, but will not withstand sudden shocks. In connection with the manufacture of our pipes more than 5,000 test bars have been made and broken, and I think I can safely say that as the result of these tests the quality of the iron used has been kept at a much higher standard than is usual. The specifications require that bars 2 inches by 1 inch in section, placed flatwise on supports 24 inches apart and loaded at the center, shall support a weight of 1900 pounds and show a deflection of 0.3 of an inch before breaking.

During the early part of the work difficulty was experienced in meeting these requirements at some of the foundries. But an improvement was made in the quality of the iron, and for the past two years there has been no difficulty in fulfilling them, and at some of the foundries the test bars show an average transverse strength of between 2,300 and 2,400 pounds with a deflection of from 0.4 to 0.45 of an inch.

### SMOOTHNESS OF PIPES.

Considerable attention has been given to having the interior surface of the pipes as smooth as possible. In making the pipes the outside surface of the core which forms the inner surface of the pipes is blacked or covered with a thin coating of coal dust and molasses, which at most foundries is applied with a brush. The men doing this work are very apt to be careless in applying the coating, leaving the surface of the core covered with small ridges and grooves, which are reproduced on the interior of the pipes. At one foundry the experiment was successfully tried of applying this coating by means of what is termed at the foundry a "Strike." The clay core was revolved in front of a straight edge, and the blacking left true and smooth as if turned in a lathe. Where the coating was applied in this manner the interior of the pipe was very much smoother than where it was done in the other way; and there is no doubt but that the roughness of the interior of a pipe due to these ridges is sufficient to sensibly affect the delivering capacity of the pipes.

### COATING.

Many experiments were tried in the hope of finding a coating for the pipes which would be a more perfect protection against the

formation of tubercles than the tar coating which is ordinarily used, and our contracts provided that, if required, the pipes should be coated with a different compound, which we might provide or require. The results of the experiments, which were made with different kinds of tar and asphalt, did not warrant any change in the previous practice, other than an endeavor to have the utmost care used in the application of the coating.

So far as our experiments have gone, the result has been rather negative; and we have not been able to find any coating which, considering probable durability and cost, would warrant any change in the material used for coating pipes at the foundries. The question is one worthy of further careful study.

At some of the foundries the ovens in which the pipes are heated before being immersed in the coal-tar bath were arranged in such a way that one end of the pipe would be very much hotter than the other, with the result that one end of the pipe would be so hot as to burn and destroy the coating, while the other end might not be hot enough. The tar-coating in the bath would not dry if it was applied to a cold pipe, and the distillation of the lighter products of the mixture is completed by the heat of the pipe after its removal from the bath. Consequently, if the pipe is too hot, distillation is carried too far, and if it is too cold, it is not carried far enough; and that is a reason why the coating of some pipes becomes soft when exposed to the rays of the sun, while in other cases it is exceedingly brittle.

A common practice in coating pipes is to immerse them in the bath for too short a time, in many cases not more than two minutes. All of our pipes were kept in the bath for five minutes, in order that all bubbles of air might be given an opportunity to escape, and that the temperature of the iron might be more uniform when taken from the bath. In other respects the coating has been applied at the several foundries in the usual manner.

The material used at all the foundries for coating pipes is, so far as I know, coal tar, but its composition varies greatly. In some cases, the crude tar is used as it comes from the gas works, and the lighter products of distillation are driven off, either by the heating of the material in the dipping tank, or, as before explained, by the heat of the pipe itself. In some cases, dead oil, which is a product of distillation of coal tar, is used for the purpose of thinning the

mixture or bath. In other cases, where the crude tar is used as it comes from the gas works, when the mixture becomes too thick in the bath, fresh tar is put in. Nowhere is linseed oil now used, nor has it been used, except in a very few instances, for many years. Many water pipe specifications call for the use of linseed oil, but the request is seldom if ever complied with, and I seriously doubt whether the pipe coating would be improved by its use. If the coating is not brittle, but is tough and smooth, I question whether it is not as good done by present methods as it would be if linseed oil were added.

The interior surfaces of nearly all of our pipes of sizes 36 inches in diameter and larger have been painted with paraffine or vulcanite applied cold with a brush. This was done by the men employed to unload the handle pipes at the several pipe yards, and being done in this way the cost has been very small. The object of doing this has been as an additional protection against rusting, in the hope that any minute holes in the covering might be covered, and that any injury done to the coating during transportation might be remedied. Both of these substances are coal tar paints, containing no linseed oil. The paraffine varnish is imported from Holland, and the vulcanite came from New York. Both of these varnishes appeared to have less volatile solvents than most of the coal tar paints and dried more slowly.

DISCUSSION.

MR. PORTER. Mr. Brackett's remarks about the necessity of protecting steel pipe against corrosion brought to my mind an interesting practice, which I presume many of the members have read about in the engineering papers during the last year, and that is what the French engineers have been doing in providing conduits for carrying the sewage of the city of Paris. It is being distributed on fields outside the city, and they are carrying it to those fields in conduits, some of which run under considerable pressure; and they have been using, as I have read, pipes having a steel core, a thin core, embedded in cement. Those are not quite the same as the cement-lined pipes which have been used in some of our New England cities, because they seem to have outside and inside of this core a sort of coarse net-work made of steel rods, and the whole thing is embedded in a thick coating of cement. They seem to have

used these under pressures as high as a 130 feet or thereabouts, and of diameters ranging from about a foot up to three feet and a half; and they have conduits of somewhat similar construction, which I judge do not run under pressure, up to about ten feet in diameter.

It seemed to me it was a very interesting practice and worth while calling attention to at this time.

MR. FITZGERALD. How much did the pipe cost, Professor?

MR. PORTER. I can't say definitely about that, but I noticed that the price of the pipe laid and the trenches backfilled ranged from about 85 cents for the smaller sizes up to about $5 for the largest, 3½ feet. The least covering was between 3 and 4 feet in depth, and how much the excavation amounted to in other places I cannot say. Those were the prices per foot.

## CLEANING A WATER MAIN IN ST. JOHN, N. B.

BY WILLIAM MURDOCH, C. E., ENGINEER WATER WORKS.

The city of Saint John is supplied with water from two sources about 12 miles apart, the east side of the harbor, which contains the larger part of the population, taking its water from Little River, and the west side supply coming from Spruce Lake.

The east side mains are three in number, as follows: No. 1, laid in 1851, 12 inches diameter; No. 2, laid in 1857 and No. 3, laid in 1873, each 24 inches diameter. Neither of the pipes had ever been cleaned and Nos. 1 and 2 had not been varnished. No. 3 however, was coated according to Dr. Smith's process. The length of each main is 4¼ miles.

The reservoir from which the supply is taken is formed by damming the river with an embankment 300 feet in length and 20 feet high, causing the surface to stand at an elevation of 160 feet above H. W. datum in the harbor, whilst the summit of the city is 130 feet above datum and five miles from the reservoir. It will thus be seen that with a gravitation system, the pressure on the summit is very low; indeed, in zero weather, it has been known to disappear entirely and the water actually fall away from the pipes and leave them empty.

The two older mains had become so foul through internal incrustation that when No. 3 was shut off for repairs and the city depended on the other two pipes, all the portions at a height of 80 feet or more above datum, comprising an area of about 200 acres and containing a population of about 8500 souls, were without water. On the other hand, with No. 2 shut off and supply coming by Nos. 1 and 3, every pipe was full and water delivered at a level of 130 feet. This was an ample demonstration of the foulness of the old mains as compared with that last laid.

In the summer of 1897, the Common Council passed an order directing that the mains be cleaned, and preparations were forthwith begun. There being no hatch boxes on these pipes, such

fittings were designed and cast, and when they were placed in position the work of cleaning began. Meanwhile a scraper was designed and constructed in the workshops of the department, the pistons being of birch, built in layers crossing the grain and bolted together as shown in cut (Fig. 1). The spindle connecting the

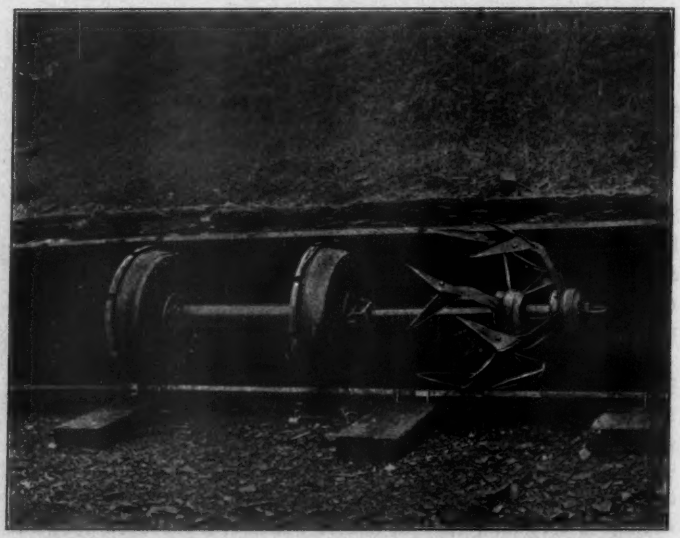


FIG. 1. FIRST SCRAPER USED.

pistons is of 3 inch wrought iron pipe, and the flanges of the ordinary kinds screwed on and rivetted to prevent backing out and falling apart when inside the pipe. Projecting beyond the forward piston is an iron rod, fitted with two sets of radial arms, four in each set, sloping back, as shown in the photograph. During the operations in the year 1897 this style of arm and cutters was used, and with this we will first deal. Each arm consisted of one layer of No. 10, B. W. G. spring steel, two inches wide, and was fitted with a forged steel fish-tail scraper made of such a form that it passed over any hard obstructions and yet reduced the incrustation considerably with each cut.

The only main operated upon, thus far, has been No. 2, which

had an internal coating of tubercles varying up to about one inch in height, closely packed all over the interior surface of the pipe and resembling in appearance that of a coarse, pebbly walk. As soon as the first section, which extended from the reservoir toward the city, a distance of about 6330 feet, had been prepared with a hatch box at each end, the cleaner was sent through and given three runs in one afternoon, the time taken in each case being about 20 minutes.

There is one flushing branch near the middle of this section and another placed at Hatch Box No. 2 which had been set close to a main stop cock, (the said stop cock being shut tight). These flushing branches were left open in each case until after the apparatus had gone by. The water on such occasions was inky black, and after running about ten minutes weakened to the color of tea. In the evening when the operations were finished a two hours' run was given to clarify the water before opening the main stop cock and placing the pipe again into service.

Section No. 2 measures about 6,860 feet and reaches to the next main stop cock near the front of which Hatch Box No. 3 was placed. In order to give the first section another cleaning, the apparatus was run through both sections, a distance of about 13,200 feet. This time our cleaner came to grief, temporarily, in the following manner: The leathers, having worn out during the first cleaning, were renewed with a harder and stiffer quality than before, but they repeatedly caught in a new joint made while inserting the hatch box. Each time the lid was removed to ascertain why the cleaner did not start, it was found firmly fixed by this imperfect butt of the two pipe ends. After twice extricating it, and again finding it caught in the same way, a jack-screw was applied to push it past this obstruction, the lid was again put on, and the water let in at 4.05 p. m, and this time it started. At each of the five flushing stations the gate was left open fully ten minutes after the cleaner had passed, and then closed. As soon as the gate was closed the cleaner again proceeded, and the scraper, *with only one piston*, reached the end of its run at 5.25 p. m., having been one hour and twenty minutes going 2.5 miles; but when 50 minutes of total stoppages are reckoned, the machine was found to have been in motion 30 minutes. As stated, only the forward part of the cleaner arrived, and search had to be made for the remainder. Nothing was done on the following day, which was Sunday, the

castaway piston, which was lying obliquely somewhere in the pipe, having but partially obstructed the flow, and the water was left on until the Monday night following.

A receiving chamber unites Nos. 2 and 3 mains, near No. 3 hatch box, and they are controlled by stop-cocks on each side of the receiver. It was therefore an easy matter to reverse the current of water in No. 3 by closing the stop-cock at the dam and opening that at the receiver, as well as the flushing branches. This was done, and men were distributed along the line to listen for a rumbling noise, which at length was heard within about a quarter of a mile of Hatch Box No. 3, from which the cleaner had been extracted. The sound was followed along the line towards the reservoir until Hatch Box No. 2 was reached, when the derelict was taken out, after having travelled nearly a mile, and crossed a valley about 90 feet in depth. It was found that the pressure of the jack-screw in forcing the cleaner past the uneven joint had cracked one of the flanges, with the result that after having travelled about 2¼ miles, the cleaner fell apart. The forward part, comprising a piston and the scraper, pushed on, but the spindle attached to the rear piston fell to the bottom of the pipe, ploughed up some dirt, and finally became embedded and jammed. The reverse current striking the piston as it did, drove it back with the spindle trailing behind. The apparatus was repaired and three more runs made through this double section of 13,200 feet, on October 29th, without any further mishap, the time taken for each run, including 10 minutes' stoppage at each of the five flushing stations, having been from 1 hour 46 minutes to 1 hour and 55 minutes. The cold weather being on when the next castings arrived, cleaning operations were suspended for the season.

On testing the efficiency of the cleaned main by shutting off No. 3 from the reservoir to the receiving chamber, where both unite, and bringing the supply through Nos. 1 and 2, it was found that the pressure in the city was as good as when No. 2 was shut and the whole supply coming through Nos. 1 and 3, thereby showing that the capacity of No. 2 had improved to such an extent that, whereas with No. 1 it had formerly delivered to a height of 80 feet only, when unassisted by No. 3, and left 200 acres of the city containing 8,500 inhabitants without water, now the whole city could be supplied without the help of No. 3, and the water rise to

a height of 130 feet above high water. The general improvement in pressure, with all the mains on, was found to be about four feet.

The operation was resumed last summer, the first run having been made June 9th, 1898, with the same apparatus as in the preceding season. After carefully studying the action of the cleaner and giving it several runs, it was found that an improvement could be made in the scraper, which was accordingly done, and each arm fitted with a steel cutter that would not clog. It was also found that the arms could be stiffened without any risk of the machine sticking, and this was done also. The final outcome of all the improvements was an apparatus of which the cut on page 338 is a photograph.

This scraper cut through all the deposit to the bare iron, an inspection at the termination of the work having shown that only the scars or imprints of the tubercles remained on the interior surface of the pipe, and it was almost as smooth as when first made.

The whole amount of material removed was not measured, as the flushing branches deliver into the brooks, and the supply of water having been abundant, the dirt was generally carried off in liquid form, the color of the liquid becoming black as the cleaner approached within one thousand feet or so of the flushing station. An estimate may be had by bearing in mind that the average thickness of the deposit was fully three-quarters of an inch, and the length of the main 22,700 feet. It will thus be seen that about 330 cubic yards were removed.

In the Marsh Creek, at the terminal flushing pipe, quite an extensive bar was formed by the material discharged from the main, the dimensions being about 12 feet by 8 feet, but the current carried a large quantity away.

When flushing into Little River, by means of three different branches within one mile of Silver Falls, the water of the Falls assumed the color of strong coffee, and Major's Brook looked like a sewer at its confluence with the Marsh Creek, though it had received the flushings of the main 7,500 feet further up. These facts are given to show the impossibility of measuring the material taken out of the pipe.

At hatch box No. 3, where the cleaner was taken out fifteen times when cleaning the upper end of the main, 108 bushels of

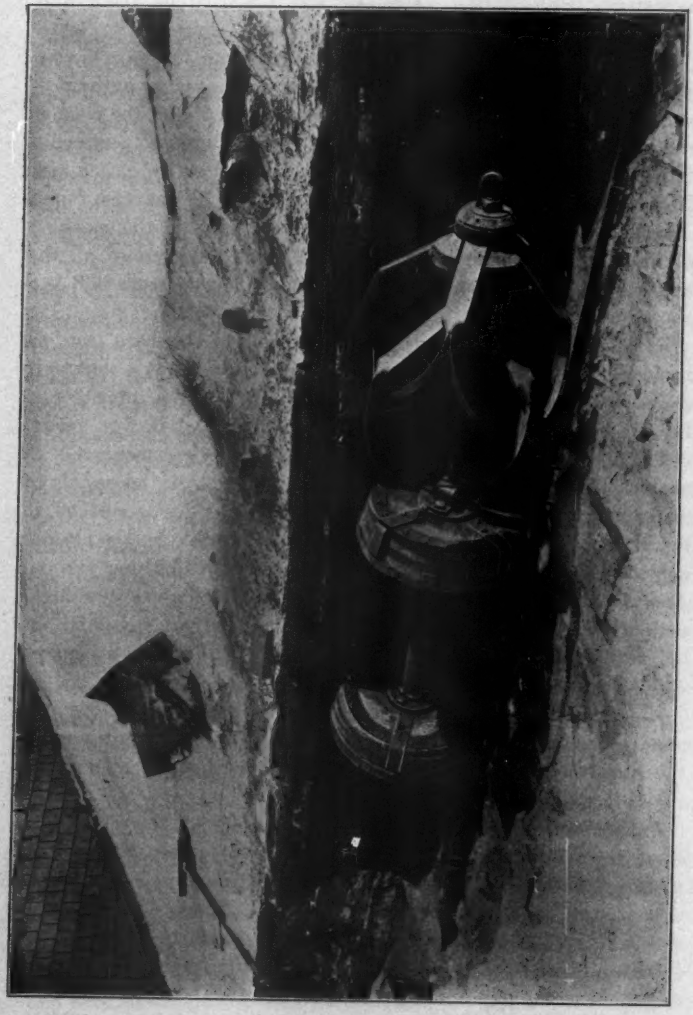


FIG. 2. IMPROVED SCRAPER USED IN 1898.

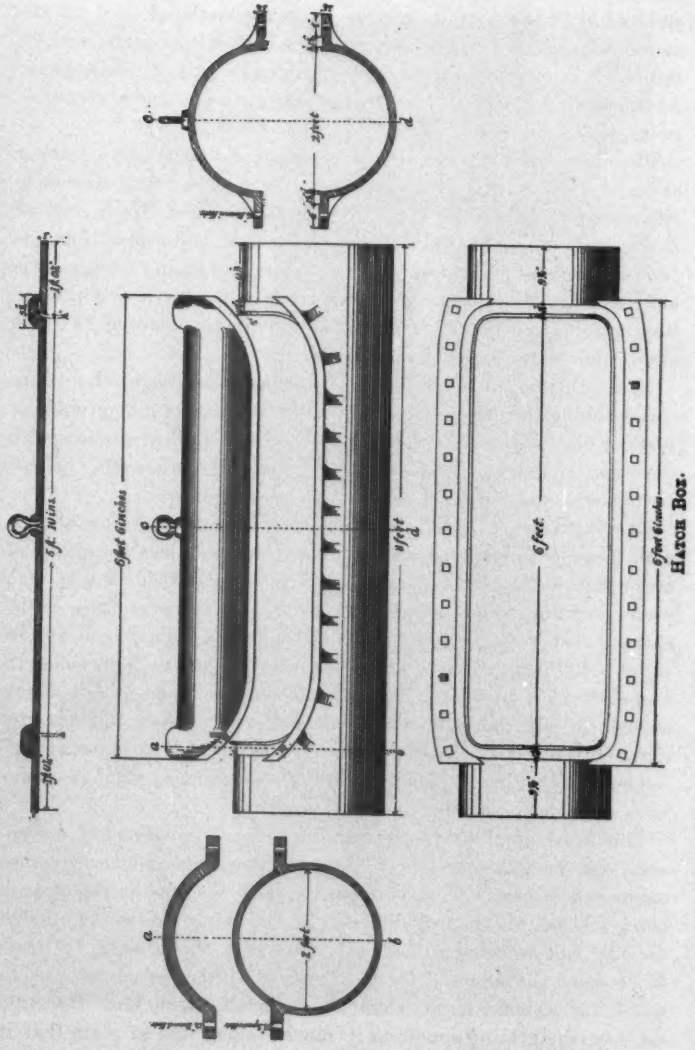
heavy material, which would not flow off by the drain, remained, and had to be taken up in buckets as it accumulated, but all the more pulverulent scrapings were carried off in the drain, and, as stated, blackened the waters of the brook upwards of a mile away. At the other hatch boxes, where the current was much stronger, an aggregate of 44 bushels had to be hoisted out.

The improvement in pressure, ascertained in the same manner as at the end of the 1897 cleaning, viz.: by sending the whole city's supply through No. 1 and No. 2, and leaving No. 3 shut off during the test, amounted to eleven feet, that is to say, that the two pipes whose combined capacity before the cleaning began was only equal to that of raising the water 80 feet, can at the present time supply the whole district and deliver up to a level of 141 feet above high water datum in the harbor.

The lightness of the cleaner is a great advantage, the entire weight being but 263 pounds, and the bulky portion being made of wood, which weighs less than the water itself, it floated along with the water. This quality was well exemplified when the broken portion was taken from the main, as already related.

The hatch boxes are of cast iron, consisting of a section of pipe with the upper half removable, and secured in place by means of screw bolts and nuts, the flanges being gasketted with Tuck's 1¼-inch round packing, which adapted itself to all the inequalities of the casting, and to the curved form of the flange. Each one weighs about 3,300 pounds, and takes 26 square-necked bolts, besides 18 feet of Tuck's packing. On completing each one, the pit was walled up with dry rubble and covered with timber, outside the city. Inside the city, the covering was arched in masonry and cement, and an iron manhole left in the crown, the manhole being large enough to pass the cleaner through.

The force employed to operate the cleaner consisted of a foreman, one mechanic, two watchers, six assistants and two express teams and drivers. The watchers walked the line on the cleaner being started, and had no difficulty in following the sound outside the city, but on coming inside the city limits, the noise of the traffic drowned the sound of the cleaner, and all that remained was to watch and wait for its arrival at the terminal hatch box. Outside the city, the grating sound as it moved along was so plain that it could be distinctly heard at a distance of 40 feet, although the


6 feet 6 inches
6 feet
HATCH BOX.

pipes have from three to six feet of covering. The duty of the teams was to transport the cleaner and men back to the first hatch box for each successive run. Men were placed at flushing stations to operate the stop-cocks—two men at each. Their duties were also to assist in operating and closing the hatch boxes and placing the cleaner.

The cost of the work was as follows:

| | |
|---|---|
| Furnishing and placing in position nine 24-inch and four 12-inch hatch boxes, being the number required on all three lines of pipe | $3,468.95 |
| Proportionate cost of installation, chargeable to No. 2 main | $1,513.15 |
| Cost of one 24-inch cleaner | 40.00 |
| Total cost of operating cleaner | 274.42 |

The runs made by the cleaner through the different sections in No. 2 main numbered fifty-seven in all, and the whole distance travelled was 94.5 miles, as follows:

| From Hatch Box. | To Hatch Box. | Number of Runs. | Distance in Miles Each Run. | Total Distance in Miles. |
|---|---|---|---|---|
| No. 1 | No. 2 | 10 | 1.2 | 12.0 |
| No. 1 | No. 3 | 16 | 2.5 | 40.0 |
| No. 4 | No. 5 | 11 | 1.0 | 11.0 |
| No. 2 | No. 3 | 9 | 1.3 | 11.7 |
| No. 3 | No 5 | 11 | 1.8 | 19.8 |

It will thus be seen that the cost of cutting this main, providing and placing five hatch boxes, quarrying stone and walling therewith the pits containing them, restoring the surface of the ground and making the cleaner, amounted to $1,553.15, or $361.20 per mile, and the operating expense of cleaning the main, which measures 4.3 miles, was $6.38 per mile of pipe cleaned.

## DISCUSSION.

MR. DEXTER BRACKETT.

In connection with Mr. Murdoch's very interesting and instructive paper, a brief description of similar work done on the Boston Water Works in 1886 and 1887 may be of interest.

The pipes laid in Boston from 1848 to 1868 were uncoated, and the interior surface of the pipes is covered with a coating of tub-

ercles from ⅜ inch to 1¼ inch in thickness. This coating, as proved by Mr. Murdoch's statistics, very seriously affects the delivering capacity of the pipes, and, in the case of the smaller sizes renders them practically useless for fire supply.

The pipes cleaned in Boston were not the supply mains, but the distributing pipes in the streets, the sizes cleaned being 6 inches and 12 inches in diameter. In cleaning these pipes the conditions were somewhat different from those of Mr. Murdoch, whose work was done on a pipe of larger size, where there were probably few, if any, service pipe connections. As many of the service stop-cocks project into the pipes from ½ inch to ¾ inch, it was necessary to have the scraper arranged so as to pass by such obstructions, and at the same time remove the coating of tubercles. The machine, which was very successfully used, consisted of a flexible central shaft about three and one-half feet in length, composed of coiled steel springs connecting small castings, to which were hinged two sets of steel scrapers, arranged radially around the shaft about twelve inches apart. The scrapers were kept against the sides of the pipe by coiled springs, which permitted them to turn back so as to pass taps or other obstacles. Back of the scrapers were two rubber pistons placed about two feet apart so as to ensure a pressure on the machine when passing branches. The scraper was operated in a manner very similar to that used by Mr. Murdoch, except that no hatch boxes were placed in the mains. A section was cut out of the pipe long enough to receive the scraper, which was then inserted, and the joints made with lead in the ordinary manner, except that clamp sleeves were used so that the section could be again easily removed and the scraper inserted if desired. A similar piece was cut from the pipe at the other end of the main to be cleaned, and the scraper was forced through the pipe by the ordinary water pressure, which varied from 30 to 45 pounds.

As occupants of buildings on the line of the pipes were without water while the work of cleaning was in progress, and as it was not thought advisable to pass the scraper through valves, the pipes were cleaned in lengths averaging 1,000 feet. The scraper generally passed through this distance in from three to four minutes, or about as fast as a man would walk. In a few instances the scraper was stopped by obstructions in the pipe, the one causing

the most trouble being lead which had run into the pipe at a joint. The water issuing from the open end of the pipe was the color of ink for from five to ten minutes after the scraper had passed through, and it was permitted to run until it became clear, after which the section of pipe was replaced and the valves opened. Some difficulty was experienced from the stopping of service pipes and house plumbing by rust forced into the pipes by the pressure of the water following the scraper, but this difficulty could be generally overcome by applying a force pump to the house plumbing and forcing the obstructions back into the main.

By this method the tubercles were removed from 58,000 feet of 6-inch pipe at a cost of 14 cents per foot, and from 20,300 feet of 12-inch pipe at a cost of 20.6 cents per foot. These prices include 5 cents per foot royalty paid for the right to use the scraper.

As was the case at St. John, a great improvement was made in the delivering capacity of the pipes by the removal of the coating of tubercles. Experiments were made to determine the friction in the pipes both before and after cleaning under different rates of discharge. The discharge was measured by means of a Deacon meter, and the friction head from readings of Bourdon gauges attached to the fire hydrants. Very great accuracy was not expected in these experiments, but they show very well the great loss in discharging capacity, caused by the coating of tubercles and the gain from the cleaning. It will be noticed that the discharge of the 6-inch tuberculated pipes was from 25% to 35% of the quantity which a clean-coated pipe might be expected to deliver under the same head, and that the discharging capacity of the pipe was more than doubled by the removal of the tubercles.

TUBERCULATED PIPE, 38 YEARS OLD—LENGTH, 525 FEET; ORIGINAL DIAMETER, 6 INCHES.

| Observed Head. Feet per 1,000. | Velocity. Feet per Second. | Observed Discharge. Gallons. | Value of c in formula $v = c\sqrt{RI}$. | Calculated discharge of clean pipe under same h'd Darcy's formula. |
|---|---|---|---|---|
| 1.30 | 0.38 | 33.3 | 29.5 | 120 |
| 2.50 | 0.57 | 50.0 | 32.2 | 165 |
| 6.90 | 0.95 | 83.3 | 32.3 | 275 |
| 14.40 | 1.13 | 100.0 | 27.1 | 395 |
| 19.20 | 1.32 | 116.6 | 27.1 | 455 |
| 25.40 | 1.51 | 133.3 | 26.8 | 525 |
| 33.80 | 1.70 | 150.0 | 26.1 | 600 |

SAME PIPE, AFTER CLEANING. LENGTH, 525 FEET; ORIGINAL DIAMETER, 6 INS.

| Observed head. Feet per 1,000. | Velocity. Feet per Second. | Observed Discharge. Gallons per Minute. | Value of c in formula $v = c\sqrt{RI}$. | Calculated discharge of clean pipe under same h'd Darcy's formula. |
|---|---|---|---|---|
| 2.70 | 0.76 | 66.6 | 41.5 | 170 |
| 1.50 | 0.95 | 83.3 | 68.8 | 125 |
| 1.50 | 1.13 | 100.0 | 82.5 | 125 |
| 3.80 | 1.51 | 133.3 | 69.4 | 205 |
| 4.20 | 1.70 | 150.0 | 74.2 | 215 |
| 6.50 | 2.08 | 183.3 | 73.1 | 265 |
| 9.40 | 2.46 | 216.6 | 71.8 | 320 |

# PROCEEDINGS.

## ADJOURNED MEETING.

PARKER HOUSE,
Boston, January 11, 1899.

President Forbes in the chair. The following members and guests were present:

### ACTIVE MEMBERS.

E. W. Bailey, L. M. Bancroft, Frank A. Barbour, George E. Batchelder, Joseph E. Beals, James F. Bigelow, George Bowers, Dexter Brackett, E. C. Brooks, George A. P. Bucknam, George F. Chace, G. L. Chapin, H. W. Clarke R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, J. J. R. Croes, A. O. Doane, W. W. Ewell, F. L. Fales, J. N. Ferguson, L. N. Farnum, B. R. Felton, Desmond FitzGerald, F. F. Forbes, F. B. French, Frank L. Fuller, W. J. Goldthwait, X. H. Goodnough, J. A. Gould, F. W. Gow, E. H. Gowing, Richard A. Hale, E. A. W. Hammett, John C. Haskell, L. M. Hastings, V. C. Hastings, Rudolph Hering, William R. Hill, Horace G. Holden, H. R. Johnson, Willard Kent, Patrick Kieran, George A. Kimball, Cyrus M. Lunt, Frank E. Merrill, John H. Perkins, George S. Rice, George J. Ries, Harley E. Royce, A. H. Salisbury, W. J. Sando, Caleb M. Saville, John E. Smith, J. Waldo Smith, Sidney Smith, George A. Stacy, Lucian A. Taylor, Robert J. Thomas, William H. Thomas, James L. Tighe, William W. Wade, Charles K. Walker, John C. Whitney, George E. Wilde, Wm. F. Williams, George E. Winslow, E. T. Wiswell, Henry B. Wood.

### ASSOCIATE MEMBERS.

Builders' Iron Foundry, Providence, R. I., by T. C. Clifford.
Chadwick Lead Works, by A. H. Brodrick.
Coffin Valve Co., by J. Alfred Welch.
Deane Steam Pump Co., by C. P. Deane
Hersey Mfg. Co., by Albert S. Glover and Samuel Harrison.
Lead Lined Iron Pipe Co., by T. W. Dwyer.
Ludlow Valve Mfg. Co., by H. F. Gould.
McNeal Pipe and Foundry Co., by I. S. Haines.
National Meter Co., by Charles H. Baldwin and J. G. Lufkin.
National Tube Works Co., by P. W. French.
Neptune Meter Co., by H. H. Kinsey.

Perrin, Seamans & Co., by H. L. Bond.
A. P. Smith Mfg. Co., by W. H. Van Winkle.
Union Water Meter Co., by F. L. Northrop.
Walworth Mfg. Co., by E. H. Rice.
R. D. Wood & Co., by Mr. Newhall.

HONORARY MEMBERS.

Engineering News, by W. M. Baker.
Fire and Water, by F. W. Shepperd.

GUESTS.

W. C. Earl and John Taylor, Weymouth, Mass.; W. T. Haines, Waterville, Me.; John Venner, Syracuse, N. Y.; W. R. Addicks, Boston, Mass.; Mr. Porter, Mr. Sweet, W. D. Kimball, William Morse, D. T. Turner, J. P. Wood and J. P. Bacon, Boston, Mass.; Mr. Ellis, Mr. Darling, Mr. Greenwood and F. P. Thorpe.

Harry F. Gibbs, Pumping Engineer, Water Works, Natick, Mass., and William T. Haines of Waterville, Maine, were elected resident active members, and John Venner, Chief Inspector of the Syracuse Water Department, Syracuse, N. Y., was elected a non-resident active member.

THE PRESIDENT. Members who attended the convention at Portsmouth or who have read the September number of the Journal, will remember that Mr. Hill, Engineer and Superintendent of the Syracuse Water Works, at that meeting invited the Association to hold its next fall meeting in that city. The matter was left with the Executive Committee, and that committee at its meeting this morning voted unanimously in favor of accepting Mr. Hill's invitation. Mr. Hill has come on from Syracuse to be with us today, and he will now explain what we may expect if we accept his invitation. I will call upon Mr. Hill to address the Association. (Applause.)

MR. HILL. Mr. President and gentlemen, I came here in behalf of the city of Syracuse for the purpose of renewing the invitation to this Association to visit our city. I assure you that we will feel greatly honored by your presence, and will endeavor to entertain you in a fitting manner, just how I do not care to say at present, but will try to do as well for you as we did for the members of the American Water Works Association who visited us last fall. The Yates Hotel, the best hotel in the city, I think could accommodate

all who would be likely to attend the convention. There is a large hall in the upper part of the building which would be suitable for us to hold our meetings in. The office of the hotel is situated on the ground floor, on a corner, and the entire front is of glass. The hotel people will permit us to put counters along this front for the exhibits, so each exhibitor will have not only an opportunity to exhibit his materials from the office itself, but he will in reality have a show window. For the larger exhibits the large writing room, which is just off the main hall, can be used.

The city of Syracuse is nicely situated for the holding of conventions. It is close to Niagara Falls, and if any party on leaving would like to make a pleasure trip they can go to the Thousand Islands and down the St. Lawrence River to Montreal, thence to Plattsburg, down Lake Champlain and Lake George to Saratoga and to Albany. Now we are very much in earnest in wanting you to visit us, and we would like to have as large an attendance as possible. We would like it if every member will come, and we would like to have you bring your wives and daughters and sweethearts, and we will try to take care of the ladies as well as of you. (Applause.)

THE PRESIDENT. You have heard what Mr. Hill has said. Now Mr. Thomas of Lowell attended the meeting of the American Society there, and I think it may be interesting if he will state briefly how that Society was entertained by the people of Syracuse.

MR. THOMAS. I had the honor of attending the convention of the American Water Works Association at Buffalo, and afterwards the pleasure of visiting Syracuse with the delegates of that convention. On the way down, a journey, I think, of about 150 miles from Buffalo to Syracuse, everything that possibly could be done was done to entertain the members and their friends, the ladies included.

When we arrived there we were furnished a lunch at the Yates House, and in the evening a banquet was given us, which was indeed a grand affair. I think about 400 people were seated in the banquet hall, among them the Mayor and the Water Commissioners and many prominent citizens of Syracuse. During the afternoon the members were taken in carriages and shown the principal points of interest in the city, and the water works system, which is well worth seeing. It would be well worth a New Eng-

land water works man's time and the expense attending it to go out there and see the water works system alone. Then the Century and other clubs were opened to the members of the Association for their entertainment; and the ladies were entertained by the women's clubs. On the whole, considering we were only in the city from noon until half-past 10 or 11 o'clock at night, the citizens of Syracuse did a great deal for us, vieing with each other in making our visit as interesting and as instructing as they possibly could. I could not begin to describe to you the pleasure and satisfaction that every member of the American Water Works Association felt at the reception we received in Syracuse; and I am sure that if the New England Water Works Association goes there for its fall meeting you will all be pleased and will be spendidly entertained. (Applause.)

MR. BANCROFT. I move that we accept Mr. Hill's invitation. Adopted.

MR. FITZGERALD. I move you, Mr. President, that the thanks of the Association be extended to Mr. Hill and to the City of Syracuse for this very cordial invitation. I think an invitation that includes not only the members, but their wives and sweethearts, is one that should receive a response from every beating heart. (Applause and laughter.)

(Mr. Coggshall seconded the motion and it was adopted.)

Mr. Dexter Brackett, engineer distribution department, Metropolitan Water Board, read a paper on "Cast iron pipes used in the Metropolitan Water Works."

Mr. George S. Rice, civil engineer, Boston, gave a description of the new steel force main of the New Bedford Water Works.

Mr. E. Kuichling, chief engineer of the Rochester Water Works, sent a communication, which was read by Mr. Coggshall, concerning the old riveted wrought iron conduit in Rochester.

Mr. L. M. Hastings, city engineer of Cambridge, read a paper on "The use of steel for water mains."

Frank A. McInness, assistant engineer, Engineering Department, Boston, gave a "Description of the new salt water fire system of Boston, Mass."

The papers were illustrated by lantern slides, and the exercises were enlivened by music by the Beethoven Male Quartette.

## OBITUARY.

DAVID BATCHELDER KEMPTON.—Died March 4th, 1899, aged 81 years. Joined this Association June 16th, 1886.

Mr. Kempton was actively engaged in early life in the management of vessels engaged in the whale fishery from New Bedford, Mass., and was a member of the Council of that city from 1863 to 1865, when the first steps toward the introduction of a public water supply was taken. He was one of the Commissioners who constructed the system and a member of the first Water Board, and was connected with the Water Board for over twenty-five years. In 1889 and 1890 he was a member of the Massachusetts Legislature, serving on the Committee on Water Supply. Mr. Kempton took a deep interest in the affairs of this Association, being a careful reader of its literature and a regular attendant at its Annual Conventions, where his familiar face and genial presence will be greatly missed in the future.

GEORGE E. BATCHELDER.—Died March 12, 1899, aged 63 years. Joined this Association June 19th, 1884.

Mr. Batchelder was a native of Middleton, Mass., and settled in Worcester, Mass., in 1869, representing that city in the Common Council and State Legislature. He was appointed Water Registrar in 1884 and continued in that office until his death, showing great executive ability in its management.

He was a veteran of the Civil War and a prominent Mason.

In this Association his judgment and ability was early recognized, being elected a member of the Finance Committee, 1885 to 1888, Vice-President 1892, President 1893 and Treasurer from 1894 until his death. Being one of the older members of this Association and a regular attendant at its meetings, his wise council will be greatly missed by many members who, attracted by his strong personality and kindly manner, are proud to be numbered among his friends.

JESSE GARRETT.—Died April 27, 1899, aged 65 years.

Mr. Garrett had represented the firm of R. D. Wood & Co., Associate members, at meetings of this Association since 1886, having been in the employ of this firm over 30 years, and the senior member of its staff.

He contributed a scholarly and instructive paper on "Making Cast Iron Pipe," which was published in Vol. XI of the Journal.

Mr. Garrett's courtly instinct prevented obtruding his business at meetings of the Association, while his active interest made his presence ever welcome. His loss will be mourned by a host of personal friends.